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ON THE EXPERIMENTS WITH THE PERKINS MACHINERY OF THE STEAM YACHT "ANTHRACITE."

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(Continued from page 17.)

EXPERIMENT MADE AT THE NEW YORK NAVY YARD WITH THE MACHINERY OF THE STEAM YACHT "ANTHRACITE" TO ASCERTAIN ITS ECONOMIC DEVELOPMENT OF POWER.

The following table contains the data and results of the experiment made by the Board of Naval Engineers on the machinery of the steam yacht *Anthracite* to ascertain its economic development of power, the vessel being secured stationary to the wharf of the New York navy yard. For facility of reference the quantities have been arranged in groups, and the description of each is so full that but little additional explanation is required.

The experiment continued, uninterruptedly, 23 hours and 58 minutes, during which all the conditions were maintained as uniformly as possible. The machinery throughout this time was operated by Mr. Perkins' engineers and fireman in the manner which their experience had taught them would produce the highest economic results.

The fuel was semi-bituminous coal from the Cumberland mines in Maryland, and was rather below the average quality. The experi-

ment was commenced with a clean fire in full action, after the machinery had been several hours in operation, and was ended with the fire in the same condition as regards cleanliness and thickness as nearly as could be judged by the eye. The coal was accurately weighed on shore into bags of uniform weight and delivered on board as required, the bunkers of the vessel having been previously sealed. The time of emptying each bag was noted in the steam log or engine room record. The fire was kept well cleaned, leveled, and free of holes; and all the refuse from the coal, in ash, clinker, soot and dust was carefully weighed in the dry state.

The quantity of feed water pumped into the boiler during the experiment was accurately measured in two iron tanks placed on the vessel's deck and filled alternately by the water of condensation delivered from the condenser by the air pump. At the end of the experiment the level of the water in the glass gauge of the boiler was made the same as at the beginning, and the quantity required for this purpose was measured in the tanks with the rest. The weight of water was calculated from the carefully measured contents in cubic feet of the tanks, the number of tankfuls emptied, and the weight of the water per cubic foot at the temperature it had in the tanks. The exact time at which each tankful was emptied was noted in the steam log.

The number of double strokes made by the pistons of the engine, or revolutions of the main shaft, were given by a counter worked by the engine, the number on the counter being entered half hourly in the steam log.

The steam pressure in the boiler and in the receiver was noted from gauges in the engine room, and entered half hourly in the steam log, as well as the vacuum in the condenser, and the height of the barometer. The throttle valve was carried wide open during the entire experiment. At half hourly intervals the temperatures were noted of the external atmosphere on deck, of the air in the engine room, of the injection or sea water, of the water discharged overboard by the circulating pump, of the feed water in the hot well, and of the feed water in the tanks. The following table contains the means of all these half hourly observations. The temperatures given in the table of the steam in the boiler, and in the first cylinder at the commencement of the stroke of its piston, considered as saturated in both cases, are cal-

culated from a formula deduced from the experiments of the French Academy and of the Franklin Institute.

During the experiment a complete set of indicator diagrams were taken every half hour, the means from all which are given in the following table. Four indicators were employed and they remained permanently in position, attached to the cylinders by short straight pipes. A set of diagrams comprised one from the top of the first cylinder, one from the bottom of the second cylinder, and two respectively from the top and bottom of the third cylinder. There were taken in all one hundred and ninety-two diagrams.

The point at which the steam was cut off in the first and third cylinders, respectively, was obtained from the diagrams and corresponds to the point of inflection between the throttled and expansion curves.

The pressures in the cylinders are the means given by all the diagrams, which were measured for the pressure at the commencement of the stroke of the piston, at the point of cutting off the steam, and at the end of the stroke of the piston, all above zero or the line of no pressure as given by the barometer. The mean back pressure against the pistons during their stroke, and the back pressure at the commencement of the stroke, are given, both above zero, the latter back pressure is the minimum in the cylinder. The indicated pressure, representing the mean ordinate of the diagrams, was obtained by a planimeter. The net pressure given in the table is the indicated pressure less two pounds per square inch of pistons allowed for overcoming the friction *per se* of the moving parts of the engine. What is called the total pressure on the piston is the sum of the indicated pressure upon, and of the mean back pressure against, the piston during its stroke.

Some explanation may be required as to the calculation of the various horses-power given in the table, and the uses made of them. Of course, the indicated and the net horses-power developed in the different cylinders are calculated from the entire areas of their respective pistons and for the indicated and net pressures upon them. The total horses-power developed in the first cylinder are also calculated in the same manner from the total pressure on the piston and from its entire area. The total horses-power developed in the second cylinder, while calculated for the total pressure upon its piston per square inch, are not calculated for the entire area of its piston, but only for the annular space remaining after the area of the piston of the first cylinder has

been deducted from the area of the piston of the second cylinder. In like manner, the total horses-power developed in the third cylinder is not calculated for the entire area of its piston, but for only the annular superficies left by the subtraction of the area of the piston of the second cylinder from the area of the piston of the third cylinder, and for the total pressure upon that superficies in pounds per square inch.

In the compound engine, the back pressure overcome by the piston of the small cylinder is more or less utilized upon or transferred to the piston of the large cylinder, where, for a superficies equal to the area of the piston ot the small cylinder, it develops a pressure equal to the sum of the indicated and back pressures per square inch upon the piston of the large cylinder. Thus a portion of the indicated horses-power developed *in* the large cylinder is really developed *by* the piston of the small cylinder. The only portion of the indicated horses-power developed *in* the large cylinder that is developed *by* its piston is what is due to the remainder of the area of that piston after subtraction of the area of the piston of the small cylinder. And the total horses-power developed by the piston of the large cylinder is what is due to the annular superficies left by the above subtraction and to the total pressure upon it composed of the sum of the indicated and back pressures upon the piston of the large cylinder per square inch.

The total horses-power represents the entire dynamic effect produced by the steam, and, in the compound engine, as in the simple engine, would be the sum of the indicated horses-power developed in the small cylinder and in the large cylinder, and of the horses-power required to overcome the back pressure against the piston of the large cylinder, the latter power being calculated for the entire area of the piston of the large cylinder and for the back pressure against it in pounds per square inch above zero, were there no loss of pressure due to the transfer of the steam from the small to the large cylinder, but as there always is such loss it amounts to its value of back pressure against the piston of the small cylinder not utilized as pressure upon the piston of the large cylinder. With the same back pressure against the piston of the large cylinder of the compound engine as against the piston of the simple engine, and with the sum of the indicated pressures on the pistons of the compound engine reduced to the area of its large piston, equal to the indicated pressure on the piston of the simple engine, there will always be a less proportion of the total pressure utilized in

the compound than in the simple engine. In the compound engine, then, the total horses-power is the sum of the indicated horses-power and the horses-power required to overcome the back pressures against the pistons, calculating the latter power separately for each piston. It is essential to know, not only the total horses-power developed by the engine as a whole, but the fractions of that power developed by the piston of the small cylinder and by the piston of the large cylinder; because, in calculating the weight of steam accounted for by the indicator at any point of either piston after the closing of the cut-off valve, it is necessary to know not only the pressure of steam at said point, but also the total horses-power which have been developed up to that point by the expanded steam alone, that is, by the steam after the closing of the cut-off valve, the weight of steam condensed in the cylinder to furnish the heat transmuted into the total horses-power developed by the expanded steam alone having to be added to the weight due to the pressure at the given point.

In calculating the weight of steam accounted for by the indicator at the point of cutting off the steam in the small cylinder nothing is to be added for condensation in the cylinder due to transmutation of heat into the total power developed up to that point, the heat for that purpose having been expended in the boiler during the generation of the steam. After the closing of the cut-off valve in the small cylinder all the steam thenceforth used to the end of the stroke of the piston of the large cylinder is expanded steam.

In calculating the weight of steam accounted for by the indicator at any point, from the steam pressure there present, allowance must be made for the weight of steam already in the clearance and steam passage of the cylinder when the boiler steam enters, as only the excess over this weight has been drawn from the boiler. The weight of steam in the clearance and steam passage present when the boiler steam enters is calculated from the back pressure against the piston at the commencement of its stroke, and not from the mean back pressure during its stroke. This is why the back pressure at the commencement of the stroke of the pistons is given separately in the table.

The economic results are given for the cost of the indicated, net and total horse-power in pounds of coal, in pounds of the combustible portion of the coal, in pounds of feed water, and in Fahrenheit units of heat consumed per hour. Of these, the latter alone is exact for comparison with the performances of other engines. The cost in pounds of feed

water does not include the difference in the total heats of steam of different pressures, and in the total heats of feed water of different temperatures, which the cost in units of heat does. The cost in fuel is variable with the quality of the fuel, with the rate of its combustion, with the kind and proportions of boiler in which it is consumed, and with the skill of the fireman; the fuel measure is therefore not a proper one for the economic efficiency of the engine, *per se*, as compared with that of other engines, for which purpose it furnishes but a rough approximation. The true engineering comparison is for the cost of the *total* horse-power in units of heat consumed per hour. For commercial purposes the comparison should be for the cost of the *net* horse-power in units of heat consumed per hour. The total horse-power representing the entire work done by the steam, both usefully and in overcoming prejudicial resistances within the machine itself, while the net horse-power represents only the work done at the crank pin, which is the useful work available for purposes exterior to the machine itself. The number of Fahrenheit units of heat expended per hour per indicated, net and total horse-power developed by the engine, is the product of the multiplication respectively of the pounds of feed water consumed per hour per each of the said horse-powers by the number of units of heat put into that water, namely, the difference between the total heat of the boiler steam and the total heat of the feed water.

If the object be to compare the economic efficiency of two systems of machinery, as a whole, including engine, boiler, method of using the steam, etc., then the cost of the *net* horse-power developed in pounds of fuel consumed per hour is the proper measure, taking care that the fuel used is the same in both cases.

In the various calculations of the quantities in the following table allowance has been made for the different specific heats of water at different temperatures and under different pressures. Also for the different total and latent heats of steam of different pressures. All the steam in the cylinders was in the saturated state, as appears from the difference in the weight of steam accounted for at any point by the indicator and the weight drawn from the boiler.

All the various quantities observed during the experiment were carefully noted personally by experienced assistant engineers of the Navy under the supervision of the Chief Engineers composing the Board. The indicator diagrams were taken by these assistants with every precaution, the indicators having been previously tested, as were

also the scales used for weighing the coal and its refuse. Every attention was given to have the results minutely accurate. The cylinders, on trial, showed no leakage, and it is believed the entire machinery was in excellent condition.

Table containing the Data and Results of the Experiment made at the New York Navy Yard on the Machinery of the Steam Yacht ANTHRACITE *by a Board of United States Naval Engineers.*

	Date of experiment (vessel secured stationary to wharf),	August 13, & 14, 1880.
	Number of sets of indicator diagrams, taken half-hourly,	48·
TOTAL QUANTITIES.	Duration of the experiment in hours and minutes, consecutively,	23 58
	Total number of pounds consumed of Cumberland semi-bituminous coal,	4400·
	Total number of pounds of refuse in ash, clinker, etc., from the coal,	776·
	Total number of pounds of combustible (gasifiable portion of the coal) consumed,	3624·
	Per centum of the coal in refuse of ash, clinker, etc.,	17·6363
	Total number of pounds of feed water pumped into the boiler,	35114·
	Total number of double strokes made by the pistons of the engine,	148154·
ENGINE.	Steam pressure in the boiler, in pounds per square inch above the atmosphere,	316·50
	Steam pressure in the receiver, in pounds per square inch above the atmosphere,	10·54
	Position of the throttle valve,	Wide open.
	Fraction completed of the stroke of the piston of the 1st cylinder when the steam was cut off,	0·5206
	Fraction completed of the stroke of the piston of the 3d cylinder when the steam was cut off,	0·2835
	Number of times the steam was expanded,	25·7098
	In none of the cylinders was the steam cushioned, nor was there either steam or exhaust lead.	
	Vacuum in the condenser, in inches of mercury,	26·75
	Height of the barometer, in inches of mercury,	30·023
	Back pressure in the condenser, in pounds per square inch above zero,	1·6066
	Number of double strokes made per minute by the steam pistons,	103·02782

Temperatures.	Temperature, in degrees Fahrenheit, of the external atmosphere,	77·5
	Temperature, in degrees Fahrenheit, of the engine room,	98·5
	Temperature, in degrees Fahrenheit, of the injection, or sea water,	76·0
	Temperature, in degrees Fahrenheit, of the discharge water,	95·0
	Temperature, in degrees Fahrenheit, of the hot well,	122·0
	Temperature, in degrees Fahrenheit, of the feed water in the tanks,	120·5
	Temperature, in degrees Fahrenheit, of the steam in the boiler, considered as saturated,	420·0
	Temperature, in degrees Fahrenheit, of the steam in the 1st cylinder at the commencement of the stroke of the piston, considered as saturated,	385·0
Rate of Combustion.	Pounds of coal consumed per hour,	183·5883
	Pounds of combustible consumed per hour,	151·2101
	Pounds of coal consumed per hour per square foot of grate,	11·9869
	Pounds of combustible consumed per hour per square foot of grate,	9·8728
	Pounds of coal consumed per hour per square foot of outer heating surface,	0·6115
	Pounds of coal consumed per hour per square foot of inner heating surface,	0·8142
	Pounds of combustible consumed per hour per square foot of outer heating surface,	0·5036
	Pounds of combustible consumed per hour per square foot of inner heating surface,	0·6706
Steam Pressures in 1st Cylinder per Indicator.	Pressure on piston of 1st cylinder at commencement of its stroke, in pounds per square inch above zero,	201·64
	Pressure on piston of 1st cylinder at the point of cutting off the steam, in pounds per square inch above zero	169·12
	Pressure on piston of 1st cylinder at the end of its stroke, in pounds per square inch above zero,	91·50
	Mean back pressure against piston of 1st cylinder during its stroke, in pounds per square inch above zero,	45·95
	Back pressure against piston of 1st cylinder at commencement of its stroke, in pounds per square inch above zero,	36·57
	Indicated pressure on piston of 1st cylinder, in pounds per square inch,	110·98
	Net pressure on piston of 1st cylinder, in pounds per square inch,	108·98
	Total pressure on piston of 1st cylinder, in pounds per square inch above zero,	156·93

Steam Pressures in 2d Cylinder per Indicator.	
Pressure on piston of 2d cylinder at commencement of its stroke, in pounds per square inch above zero,	60·00
Pressure on piston of 2d cylinder at the end of its stroke, in pounds per square inch above zero,	31·30
Mean back pressure against piston of 2d cylinder during its stroke, in pounds per square inch above zero,	31·06
Back pressure against piston of 2d cylinder at commencement of its stroke, in pounds per square inch above zero,	30·20
Indicated pressure on piston of 2d cylinder, in pounds per square inch,	10·537
Net pressure on piston of 2d cylinder, in pounds per square inch,	8·537
Total pressure on piston of 2d cylinder, in pounds per square inch above zero,	41·597
Steam Pressures on 3d Cylinder per Indicator.	
Pressure on piston of 3d cylinder at commencement of its stroke, in pounds per square inch above zero,	27·71
Pressure on piston of 3d cylinder at the point of cutting off the steam, in pounds per square inch above zero,	22·28
Pressure on piston of 3d cylinder at the end of its stroke, in pounds per square inch above zero,	9·55
Mean back pressure against piston of 3d cylinder during its stroke, in pounds per square inch above zero,	4·21
Back pressure against piston of 3d cylinder at commencement of its stroke, in pounds per square inch above zero,	3·74
Indicated pressure on piston of 3d cylinder, in pounds per square inch,	12·457
Net pressure on piston of 3d cylinder, in pounds per square inch,	10·457
Total pressure on piston of 3d cylinder, in pounds per square inch above zero,	16·667
Boiler Vaporization.	
No. of pounds of water that would have been vaporized in the boiler had the feed water been supplied at the temperature of 100 degrees, and vaporized under the atmospheric pressure of 29·92 inches of mercury,	36509·6289
No. of pounds of water that would have been vaporized in the boiler had the feed water been supplied at the temperature of 212 degrees, and vaporized under the atmospheric pressure of 29·92 inches of mercury,	40775·4371
Pounds of water vaporized from 100° Fahrenheit by one pound of coal,	8·2976
Pounds of water vaporized from 100° Fahrenheit by one pound of combustible,	10·0744
Pounds of water vaporized from 212° Fahrenheit by one pound of coal,	9·2671
Pounds of water vaporized from 212° Fahrenheit by one pound of combustible,	11·2515

Horses-power.	Indicated horses-power developed in the 1st cylinder,	20·4308
	Indicated horses-power developed in the 2d cylinder,	7·8290
	Indicated horses-power developed in the 3d cylinder,	39·4483
	Aggregate indicated horses-power developed in all the three cylinders,	67·7081
	Net horses-power developed in the 1st cylinder,	20·0628
	Net horses-power developed in the 2d cylinder,	6·3430
	Net horses-power developed in the 3d cylinder,	33·1150
	Aggregate net horses-power developed in all the three cylinders,	59·5208
	Total horses-power developed in the 1st cylinder,	28·8902
	Total horses-power developed in the 2d cylinder,	23·2490
	Total horses-power developed in the 3d cylinder,	28·0133
	Aggregate total horses-power developed in all three cylinders,	80·1525
	Total horses-power developed by the expanded steam alone in the 1st cylinder,	10·7400
	Total horses-power developed by the expanded steam alone in the 2d cylinder,	23·2490
	Total horses-power developed by the expanded steam alone in the 3d cylinder,	28·0133
Weight of Steam accounted for by the Indicator.	Pounds of steam present per hour in the 1st cylinder at the point of cutting off the steam, calculated from the pressure there,	633·5094
	Pounds of steam present per hour in the 1st cylinder at the end of the stroke of its piston, calculated from the pressure there,	609·6268
	Pounds of steam condensed per hour in the 1st cylinder to furnish the heat transmuted into the total horses-power developed in that cylinder by the expanded steam alone,	30·8817
	Sum of the two immediately preceding quantities,	640·5085
	Pounds of steam present per hour in the 2d cylinder at the end of the stroke of its piston, calculated for the pressure there,	808·3992
	Pounds of steam condensed per hour in the 1st and 2d cylinders to furnish the heat transmuted into the total horses-power developed in those cylinders by the expanded steam alone,	93·9542
	Sum of the two immediately preceding quantities,	902·3534
	Pounds of steam present per hour in the 3d cylinder at the end of the stroke of its piston, calculated for the pressure there,	1150·7924
	Pounds of steam condensed per hour in the 1st, 2d and 3d cylinders to furnish the heat transmuted into the total horses-power developed in those cylinders by the expanded steam alone,	167·0720
	Sum of the two immediately preceding quantities,	1317·8644

Economic Results.	
Pounds of coal consumed per hour per indicated horse-power,	2·7115
Pounds of coal consumed per hour per net horse-power,	3·0844
Pounds of coal consumed per hour per total horse-power,	2·3319
Pounds of combustible consumed per hour per indicated horse-power,	2·2333
Pounds of combustible consumed per hour per net horse-power,	2·5405
Pounds of combustible consumed per hour per total horse-power,	1·9207
Pounds of feed water consumed per hour per indicated horse-power,	21·6887
Pounds of feed water consumed per hour per net horse-power,	24·6152
Pounds of feed water consumed per hour per total horse-power,	18·2791
Fahrenheit units of heat consumed per hour per indicated horse-power,	24265·69
Fahrenheit units of heat consumed per hour per net horse-power,	27603·52
Fahrenheit units of heat consumed per hour per total horse-power,	20498·22
Per Centum of Total Pressure on Pistons utilized as Indicated and as Net Pressures.	
Mean indicated pressure on the piston of the 3d cylinder, equivalent to the sum of the indicated pressure on that piston and of the indicated pressures on the pistons of the 2d and 1st cylinders, reduced respectively in the ratio of the areas of the pistons of the 2d and 1st cylinders to that of the 3d cylinder, and for the fact of the 2d and 1st cylinders being single acting while the 3d cylinder is double acting, in pounds per square inch,	21·381
Mean total pressure which applied to the piston of the 3d cylinder would produce the total horses-power developed by the engine, provided the indicated pressure on that piston was the above 21·381 pounds per square inch,	25·591
Per centum of the mean total pressure on the pistons of the three cylinders utilized as indicated pressure,	83·55
Mean net pressure on the piston of the 3d cylinder equivalent to the sum of the net pressure on that piston and of the net pressures on the pistons of the 2d and 1st cylinders reduced respectively in the ratio of the areas of the pistons of the 2d and 1st cylinders to that of the 3d cylinder, and with allowance for the fact of the 2d and 1st cylinders being single acting while the 3d cylinder is double acting, in pounds per square inch,	18·795
Per centum of the mean total pressure on the pistons of the three cylinders utilized as net pressure,	73·44

DIFFERENCE BETWEEN THE WEIGHT OF WATER VAPORIZED IN THE BOILER AND THE WEIGHT OF STEAM ACCOUNTED FOR BY THE INDICATOR.

Difference, in pounds per hour, between the weight of water (1465·11822 pounds) vaporized in the boiler and the weight of steam accounted for by the indicator, in the 1st cylinder at the point of cutting off the steam,	831·6088
Difference, in per centum of the weight of water vaporized in the boiler, between that weight and the weight of steam accounted for by the indicator in the 1st cylinder at the point of cutting off the steam, . .	56·76
Difference, in pounds per hour, between the weight of water vaporized in the boiler and the weight of steam accounted for by the indicator, in the 1st cylinder at the end of the stroke of its piston, . . .	824·6097
Difference, in per centum of the weight of water vaporized in the boiler, between that weight and the weight of steam accounted for by the indicator in the 1st cylinder at the end of the stroke of its piston, . .	56·22
Difference, in pounds per hour, between the weight of water vaporized in the boiler and the weight of steam accounted for by the indicator in the 2d cylinder at the end of the stroke of its piston, . . .	562·7648
Difference, in per centum of the weight of water vaporized in the boiler, between that weight and the weight of steam accounted for by the indicator in the 2d cylinder at the end of the stroke of its piston, . .	38·41
Difference, in pounds per hour, between the weight of water vaporized in the boiler and the weight of steam accounted for by the indicator in the 3d cylinder at the end of the stroke of its piston, . . .	147·2538
Difference, in per centum of the weight of water vaporized in the boiler, between that weight and the weight of steam accounted for by the indicator in the 3d cylinder at the end of the stroke of its piston, . .	10·05

REMARKS.

Owing to the limited time the *Anthracite* could be placed under the command of the Board of Naval Engineers at the New York Navy Yard, the trial of her machinery was restricted to one experiment, and, consequently, to one set of conditions; but the soundness of the system can be judged only from a number of experiments made under widely varying conditions, and it was the intention of Chief Engineer Loring, had the vessel been long enough at the Navy Yard, to have made a series of experiments on her machinery, with varying boiler pressures and measures of expansion. He intended to have commenced with boiler steam of 75 pounds per square inch pressure above the atmosphere, and, keeping the same measure of expansion, to have

made a series of experiments with the boiler pressure increasing 25 pounds per square inch each time; after which, keeping the same boiler pressure, he would have varied the measure of expansion as much as possible, the object being to ascertain whether as good economic results could not be obtained with the lower boiler pressures and less measures of expansion as with the higher boiler pressures and greater measures of expansion, the practically important problem being to ascertain the limit, in both cases, at which increase of economy ceased.

Comparing the economic results obtained during the single experiment made, with those given by ordinary compound engines, it is evident that the latter, with one-fourth the boiler pressure and one-fourth the measure of expansion used with the machinery of the *Anthracite*, produce the power as economically. If the trials are to cease here, the inference follows that the enormous excess of boiler pressure and measure of expansion employed with the machinery of the *Anthracite* have failed to practically realize the economy theoretically predicable, leaving the grave inconveniences of such excess of pressure and expansion unbalanced by any advantage. With this result apparent, it becomes necessary to closely examine the conditions under which the experiment with the *Anthracite* was made.

The boiler pressure does not always represent the initial pressure on the piston, and still less does it represent the mean total pressure on the piston during the stroke; yet it is the latter on which the gain by the use of high pressure must be predicated. Notwithstanding the effect of any superheating which it may be practicable to give in the boiler, the steam in the cylinder is always found to be in the saturated state, that is to say, it has always the maximum density for its pressure, so that it is useless to generate steam at high boiler pressures with the expectation of realizing the economy of producing a given bulk of such pressure over an equivalent bulk of lower boiler pressure, if the former be used in the cylinder with the same mean total pressure on the piston as the latter. To make the mean total pressure on the piston equal in the two cases, the high boiler pressure must be used with a greater measure of expansion than the low boiler pressure, and the gain due to these different measures of expansion may be something or nothing, according to the conditions, but be it what it may, it is entirely distinct from the gain due to the use of steam of the high pressure, *per se*, so that if the high pressure boiler steam be correspondingly expanded in the cylinder to produce the same mean total

pressure in its piston as in the case of the low pressure boiler steam, the only gain due to the former will be what results from the higher measure of expansion with which it is used, and not from the higher boiler pressure. This important fact has been overlooked, and a gain under these conditions expected from the high pressure steam corresponding not only to its use with a higher measure of expansion, but also to its generation under a higher boiler pressure. The two cannot be had together. To ascertain what gain can practically be obtained from steam of higher boiler pressure, in function of pressure alone, the experiment must be made using it with the same measure of expansion as in the case of the steam of lower boiler pressure against which it may be tried. This was one of the determinations that Chief-Engineer Loring would have made could he have obtained the *Anthracite* for a sufficient length of time.

Now, during the single experiment with the *Anthracite's* machinery, the measure of expansion employed was so great (25·7098 times) that notwithstanding the high initial pressure on the piston of the first cylinder (201·64 pounds per square inch above zero), the mean total pressure above zero, referred to the piston of the third cylinder, was only 25·591 pounds per square inch above zero, so that in this case the *Anthracite's* engine had no advantage over the ordinary compound engine in function of higher mean total pressure on the piston.

It is quite probable, also, that the measures of expansion employed with ordinary compound engines even when using superheated steam, say from six to ten times, give as high an economy as can be obtained from greater measures, owing to the enormous cylinder refrigeration which attends the use of steam expansively, and which is *pro rata* to the total power developed by the expanded steam alone. If such be the fact, and all experiments thus far show it, then there is no reason to expect any higher economic results from the *Anthracite's* machinery for the conditions under which it was tried at the navy yard than were actually obtained. They were equal to those of an ordinary compound engine, and nothing more.

But it is quite possible that other conditions would have given a higher economy for the *Anthracite's* engine. Had, for instance, the same initial pressure on the piston of the first cylinder been maintained with the steam expanded, say six or ten times only, then, supposing nothing of economy to be lost by the decreased measure of expansion, there would have been the gain due to the resulting higher mean total

pressure on the piston in function of pressure only, and to the fact that the same final back pressure would have been a less per centum of the mean total pressure above zero; in other words, more of the mean total pressure on the piston would have been utilized as indicated, or as net pressure. Probably, however, the boiler could not supply the engine with the increased quantity of steam, in equal times, that these conditions would require, and, if it could, the rate of combustion of the coal would have to be largely increased, which would have been attended by a decreased economic vaporization, so that although an economic gain might have been obtained according to the water measure, or weight of steam consumed, yet a loss might have been experienced according to the coal measure. It is so impossible to change one condition in engineering without changing all or many, that it is unsafe to infer what would follow from a given change in one direction. Only the actual trial or appeal to Nature can be relied on each time.

It is true that any better results obtained with the water measure could be obtained with the coal measure also, by reducing the dimensions of the cylinders so as to develop the same power in each case with the same initial pressure on the piston. This, however, requires a new engine, and could not be realized with the machinery of the *Anthracite*.

Nor must the fact be omitted that with each increase in the initial pressure on the piston, the back pressure against it remaining constant, there results increase of cylinder condensation due to the increase in the difference between the temperature of the initial pressure and that of the back pressure. Each theoretical gain is attended with its inseparable practical loss, so that only a very small margin of difference seems possible in any case, and herein lies the true explanation of the failure, total or partial, of the many promising schemes and ingenious mechanisms for cheapening the cost of steam power in fuel.

In comparing the economic efficiency of steam of exceptionally high pressure and measure of expansion against that of steam of comparatively low pressure and measure of expansion, care must be taken that the degree of superheating be the same in both cases. Now, a considerable degree of superheating will increase the economy of any steam from 15 to 30 per centum according as the engine using it is a large or a small one, and superheating is as practicable with steam of one pressure as another. When a high degree of superheating is employed with high pressures and measures of expansion, discrimination must be made between what is due to it and what is due to them.

The great economic gain certain to follow the use of a high degree of superheating is a great temptation to employ it, especially for trials too short to develop its injurious effects on the metal of the cylinder and valves, and on the superheating apparatus itself. A prolonged use of any high degree of superheating has always been followed by such decrease in the durability and reliability of the machinery that, often as it has been attempted just so often has it been abandoned, consequently, notwithstanding the great economy given by it, it is in practical use nowhere. A very moderate degree of superheating is all that can be permanently maintained.

In the boiler of the *Anthracite*, extensive provision was made for highly superheating the steam, the superheating surface being twenty times the area of the grate surface and equal to the water heating surface, an excessive proportion, as compared with the five to eight times of the grate surface, which is usually given with large superheaters. The temperature of the gases of combustion in the chimney during the navy yard experiment averaged 700 degrees Fahrenheit, as obtained from the melting points of different metals suspended in the chimney; yet, notwithstanding the great extent of superheating surface and the high temperature of the gases of combustion upon it, the steam during the navy yard experiment did not appear to be much superheated. This can only be accounted for on the supposition that the steam was very wet when it went upon the superheating surface, owing to the priming or foaming of the boiler. It is greatly to be regretted that the temperatures of the steam on leaving the boiler and on entering the valve chest of the first cylinder were not taken during the navy yard experiment. This is the only important omission in the data; these temperatures would have shown the degree of superheating with certainty, whereas it can now only be inferred. The proper thermometers for the purpose were provided, but they were not inserted in position owing to the want of time to make the extensive connections required.

During the navy yard experiment the boiler was worked with the very moderate rate of combustion of about 12 pounds of coal per hour per square foot of grate surface, which was doubtless above its economic limit. All boilers of this description, that is, composed of small tubes in direct contact with the fire and connected continuously, the boiler not having a proper area of water surface for the disengagement of the steam, nor a proper capacity, and, more especially, proper height

of steam room for the separation by gravity of the carried up water from the steam, prime or foam violently when worked above a low rate of combustion. This result is inevitable, and such boilers are only fit for low rates of combustion, and even then require large proportions of water heating and steam superheating surfaces to give good economic vaporizations. As the rate of combustion is increased, so is the priming or foaming, and although the economic vaporization may up to a certain point be maintained by the conversion of the steam superheating into water heating surface by the priming, yet the superheating effect is thereby lost. If the rate of combustion be increased to 15, 20 or 25 pounds of coal per hour per square foot of grate surface the water will be driven by the heat entirely out of the lower tubes, and they will be quickly destroyed. A very great deal of this type of boiler is required in proportion to the power developed. It is neither durable nor reliable, particularly in ignorant or careless hands.

A proper test of this boiler requires it to be worked during a moderate time at the usual rate of combustion for steamers, say 20 pounds of coal per hour per square foot of grate surface. Its durability, its economic vaporization and its steam superheating would then become manifest; but experiments at rates of combustion considerably below what is necessary in practice only mislead.

The *Anthracite* has made two voyages across the Atlantic between Liverpool and New York, say 6500 geographical miles, and this was intended as a test and proof of the durability and reliability of her machinery. But the voyages were made at an exceedingly low rate of combustion, only about two indicated horses-power being developed for each square foot of grate surface, which evidently does not meet the objections, and leaves the problem just where it was. The fact at issue is: can the vessel without injury to her machinery make two consecutive voyages across the Atlantic at the rate of combustion employed by the ocean steamships running on the same track? The chimney of the *Anthracite* was so short that 12 pounds of semi-bituminous coal per hour per square foot of grate surface was as high a rate of combustion as could be permanently maintained. Had the vessel remained sufficiently long at the New York navy yard for exhaustive experimenting, her chimney would have been temporarily lengthened to about 55 feet above the grate, and all the coal burned that the draught would consume.

The great tendency of the boiler of the *Anthracite* to foam is evi-

denced by the fact that while the area of the steam port of the first cylinder is $\frac{1}{15}$th of the area of the piston, it was deemed prudent to make the cross area of the steam pipe less than $\frac{1}{47}$th of the area of the piston, thus providing for a great and permanent throttling of the steam beyond the control of the persons operating the engine. The extent of this throttling was such that whereas the boiler pressure during the experiment was 331·23 pounds per square inch above zero, the initial pressure on the piston of the first cylinder was 201·64 pounds, the throttle valve being wide open, the difference was 129·59 pounds.

That the steam had but little superheating when entering the first cylinder, probably not exceeding 50 degrees Fahrenheit, the most of which (35 degrees) was due to the throttling, appeared from all the indications. The packings of the valve stems and of the piston rods were unaffected; the steam when blown into the air did not look as though it was much superheated, and the condensation of steam in the first cylinder was enormous, exclusive of what was due to the development of the power. This condensation at the point of cutting off the steam in the first cylinder was 56·76 per centum of the entire weight generated in the boiler, and was maintained to the end of the stroke of the piston of that cylinder. In the second cylinder, owing to re-evaporation, this condensation fell at the end of the stroke of its piston to 38·41 per centum of the entire weight generated in the boiler, while at the end of the stroke of the piston of the third cylinder it fell further to 10·05 per centum by the continuance of the same cause.

This enormous cylinder refrigeration was due to the enormous measure of expansion (nearly twenty-six times) with which the steam was used, to the great difference between the temperature of the initial steam in the first cylinder and that of the back pressure steam in the third cylinder, and to the small dimensions of the cylinders whereby their inner surfaces, including the extensive surfaces of their disproportionately large steam passages, became very great relatively to the weight of steam contained. To counteract these cooling causes would require the steam to be very highly superheated, and provision for obtaining that effect was made by giving the boiler an enormous extent of superheating surface, but the necessary superheating was not obtained with the water carried at the experimental level, due doubtless to the priming or foaming of the boiler, notwithstanding the great throttling with which the steam was used.

A sensible proof of the enormous cylinder condensation in the case of the experiment on the *Anthracite* at the New York navy yard was

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furnished whenever a set of indicator diagrams was taken. On opening the cock in the indicator pipe of the first cylinder a steady flow of water streamed from it, of the full area of the cock opening, and with considerable velocity, and continued unabated as long as the cock remained open, making the taking of diagrams very troublesome. When the cock in the indicator pipe of the second cylinder was opened, the same flow of water took place, and continued as long as the cock remained open, but the issuing quantity of water was much less and it flowed with much less velocity, the pressure being greatly less than in the first cylinder. When the cocks in the indicator pipes of the third cylinder were opened, no water came forth at any part of the stroke of the piston.

The engine during its working gave no indication of the enormous quantities of water of condensation passing through the cylinders; there was no slapping noise or noticeable jar, the entire mass of steam condensed during the steam stroke of the pistons being re-evaporated during the latter part of that stroke and the whole of the exhaust stroke under the lessening pressures by the heat contained in the water of condensation and in the metal of the cylinders on which this water rested.

The theoretical gain due to very high steam pressure worked in a cylinder with a low and constant back pressure, and to using it very expansively, is practically lost in greater refrigeration which inseparably attends both to a greater degree than with steam of lower pressure worked less expansively, and although the resulting condensation may be in a great measure prevented by previous superheating, yet if the same quantity of superheating be given to the lower pressure and less expanded steam, the latter would be proportionally benefitted, and the relative economy of the two perhaps not much changed.

It is of the greatest importance to mankind that there shall be discovered the pressure of steam, the measure of expansion, and the degree of superheating which will produce the highest economic results from the fuel, without prejudice to the durability and reliability of the machinery, and without requiring exceptional care and skill in its management. The attempt made to solve this problem by the construction of the machinery of the *Anthracite* is in the right direction, and most praiseworthy; and it will be a subject of lasting regret should a series of exhaustive experiments be not made with it. The mechanism is at hand, and all that is needed are the services of skilled and sagacious experimenters animated by the love of truth alone.

(To be continued.)

On the Revolution of a Fluid Ellipsoid with Three Unequal Axes.

By Dr. Thomas Craig, U. S. Coast and Geodetic Survey.

In 1834 Jacobi demonstrated the curious fact that the ellipsoid of three unequal axes is a possible form of equilibrium for a rotating mass of homogeneous fluid, provided the shortest axis of the ellipsoid be taken as the axis of rotation. The substance of Jacobi's investigation is given in the next two pages before proceeding to the particular form of the problem which it is desired to investigate.

If a, b, c denote the semi-axes of an ellipsoid we have for the equation of the surface

$$\frac{x^2}{a^2} + \frac{y^2}{b^2} + \frac{z^2}{c^2} = 1 \tag{1}$$

a, b, c are taken in order of magnitude. If the fluid mass is rotating around the axis of z with angular velocity ζ, we have for the equation of a level surface

$$\Omega + \frac{\zeta^2}{2}(x^2 + y^2) = C \tag{2}$$

where Ω is the potential of the whole mass at an internal point and C is a constant for each level surface, but varies in passing from one to another. Write

$$D = \sqrt{(a^2 + t)(b^2 + t)(c^2 + t)};$$

then for the potential of an ellipsoid whose semi-axes are a, b, c at an internal point x', y', z', we have

$$\Omega = -\pi a b c \int_0^\infty \frac{dt}{D}\left\{\frac{x'^2}{a^2+t} + \frac{y'^2}{b^2+t} + \frac{z'^2}{c^2+t} - 1\right\} \tag{3}$$

Substituting this in the equation of a level surface (2) and we have on dividing through by $\frac{2}{3}M$, where M is the mass of the ellipsoid,

$$\frac{2\zeta^2}{3M} - \int_0^\infty \frac{dt}{D(a^2+t)}x' + \frac{2\zeta^2}{3M} - \int_0^\infty \frac{dt}{D(b^2+t)}\ y'^2 - \int_0^\infty \frac{dt}{D(c^2+t)}z'^2 = C_1 \Bigg\} \tag{4}$$

This equation must hold at the external surface of the ellipsoid which is given by (1) and, therefore, by comparison of these two equations we have

$$\begin{aligned} \frac{2\zeta^2}{3M} - \int_0^\infty \frac{dt}{D(a^2+t)} &= \frac{k}{a^2} \\ \frac{2\zeta^2}{3M} - \int_0^\infty \frac{dt}{D(b^2+t)} &= \frac{k}{b^2} \\ - \int_0^\infty \frac{dt}{D(c^2+t)} &= \frac{k}{c^2} \end{aligned} \tag{5}$$

Subtract the second of these equations from the first and we have

$$a^2b^2\int_0^\infty \frac{(a^2-b^2)\,dt}{D(a^2+t)\,(b^2+t)} = k\,(b^2-a^2); \tag{6}$$

eliminating k by the third equation gives

$$(a^2-b^2)\left\{\int_0^\infty \frac{(a^2-b^2)\,dt}{D(a^2+t)\,(b^2+t)} - \int_0^\infty \frac{c^2\,dt}{D(c^2+t)}\right\} = 0 \tag{7}$$

This is satisfied by $a = b$, which is the case of an ellipsoid of revolution round c; it is also satisfied by equating to zero the quantity in brackets

$$\int_0^\infty \frac{\left(a^2+b^2) - \frac{a^2b^2}{c^2}\right)t + t^2}{D^3}\,dt = 0 \tag{8}$$

There can be no negative elements in this, unless

$$c < \frac{a\,b}{\sqrt{a^2+b^2}}.$$

Imagine a right-angled triangle with sides a, b. The perpendicular from the right angle to the hypothenuse is

$$\frac{a\,b}{\sqrt{a^2+b^2}}.$$

From this it appears that c must be less than either a or b if the integral (8) is to vanish. If, however, c be very small, the integral will become negative. Therefore, there is some value of c which will satisfy the equation.* In looking over Clark's Geodesy and several

* Clark's Geodesy, pages 76 and 77.

papers by Liouville, Jacobi and others, I find no mention made of any solution of the problem of determining a possible form of equilibrium of the homogeneous fluid mass when the fluid no longer rotates round one axis but when there is rotation round three axes at right angles to each other. In what follows it is shown that the ellipsoid is a form of equilibrium of a fluid mass rotating in this manner. Equation (1) gives the ellipsoid whose semi-axes are a, b, c. If X, Y, Z are the components of the forces acting at the point x, y, z of the fluid mass we have

$$\frac{dp}{\rho} = Xdx + Ydy + Zdz \tag{9}$$

and for the free surface of course

$$Xdx + Ydy + Zdz = 0. \tag{10}$$

Let ξ, η, ζ denote the components of angular velocity round the axes x, y, z respectively; also, let Ω denote the potential of the mass at an internal point thus,

$$\Omega = -\pi\, a\, b\, c \int_0^\infty \frac{dt}{D}\left\{\frac{x^2}{a^2+t} + \frac{y}{b^2+t} + \frac{z^2}{c^2+t} - 1\right\} \tag{11}$$

or say,

$$\Omega = \text{const.} - \pi\, a\, b\, c\,(Ax^2 + By^2 + Cz^2) \tag{12}$$

where

$$A = \int_0^\infty \frac{dt}{D(a^2+t)},$$

$$B = \int_0^\infty \frac{dt}{D(b^2+t)}, \tag{13}$$

$$C = \int_0^\infty \frac{dt}{D(c^2+t)}.$$

We have now

$$X = \frac{d\Omega}{dx} + x\,(\eta^2+\zeta^2)$$

$$Y = \frac{d\Omega}{dy} + y\,(\zeta^2+\xi^2), \tag{14}$$

$$Z = \frac{d\Omega}{dz} + z\,(\xi^2+\eta^2).$$

Substituting these in (9) we have for every surface of equal pressure and density

$$\Omega + \frac{x^2}{2}(\eta^2+\zeta^2) + \frac{y^2}{2}(\zeta^2+\xi^2) + \frac{z^2}{2}(\zeta^2+\eta^2) = C \qquad (15)$$

Introducing the value of Ω and dividing through by $\frac{3}{4}M$ where M is the mass of the ellipsoid this becomes

$$\left\{\frac{2(\eta^2+\zeta^2)}{3M} - A\right\}x^2 + \left\{\frac{2(\zeta^2+\xi^2)}{3M} - B\right\}y^2 + \left\{\frac{2(\xi^2+\eta^2)}{3M} - C\right\}z^2 = C^1 \qquad (16)$$

Comparing this with (1) we have

$$\begin{aligned} \frac{2(\eta^2+\zeta^2)}{3M} - A &= \frac{k}{a^2} \\ \frac{2(\zeta^2+\xi^2)}{3M} - B &= \frac{k}{b^2} \\ \frac{2(\xi^2+\eta^2)}{3M} - C &= \frac{k}{c^2}. \end{aligned} \qquad (17)$$

Subtracting the second of these from the first we have

$$\frac{2a^2b^2}{3M}(\eta^2-\zeta^2) + a^2b^2\int_0^\infty \frac{dt\,(a^2-b^2)}{D(a^2+t)(b^2+t)} = k(b^2-a^2) \qquad (18)$$

Eliminating k by means of the third equation and reducing

$$\frac{2(a^2-b^2)(\xi^2+\eta^2)}{3M} + \frac{2\frac{a^2b^2}{c^2}(\xi^2-\eta^2)}{3M} + (a^2-b^2)\left\{\int_0^\infty \frac{dt}{D^3}\left(a^2+b^2-\frac{a^2b^2}{c^2}\right)t + t^2\right\} = 0 \qquad (19)$$

Making $\xi = \eta = 0$ we have equation (8) which corresponds to the case of rotation round one axis. Equation (19) does not bring into evidence the angular velocity ζ and in consequence is not a form that can be advantageously employed; but dividing the first and second of equations (17) by the third we obtain two relations which are independent of k, and which contain all three of the quantities ξ, η, ζ; these are

$$\frac{2(\xi^2+\zeta^2)-3MB}{2(\xi^2+\eta^2)-3MC}=\frac{c^2}{b^2}$$
$$\frac{2(\eta^2+\zeta^2)-3MA}{2(\xi^2+\eta^2)-3MC}=\frac{c^2}{a^2} \qquad (20)$$

Clear these of fractions, add and subtract $\xi^2+\zeta^2$ on the right side of the first and $\xi^2+\zeta^2$ on the right hand side of the second equation;

$$\frac{b^2}{c^2}\tfrac{3}{2}MB-\tfrac{3}{2}MC=\frac{b^2-c^2}{c^2}(\zeta^2+\xi^2)+\zeta^2-\eta^2$$
$$\frac{a^2}{c^2}\tfrac{3}{2}MA-\tfrac{3}{2}MC=\frac{a^2-c^2}{c^2}(\eta^2+\zeta^2)+\zeta^2-\xi^2 \qquad (21)$$

or,

$$\frac{b^2}{b^2-c^2}\tfrac{3}{2}MB-\tfrac{3}{2}\frac{c^2}{b^2-c^2}MC=\zeta^2+\xi^2+\frac{c^2}{b^2-c^2}(\zeta^2-\eta^2)$$
$$\frac{a^2}{a^2-c^2}\tfrac{3}{2}MA-\tfrac{3}{2}\frac{c^2}{a^2-c^2}MC=\eta^2+\zeta^2+\frac{c^2}{a^2-c^2}(\zeta^2-\xi^2) \qquad (22)$$

Introducing now the values of A, B, C, these become

$$\tfrac{3}{2}M\int_0^\infty\frac{t\,dt}{D(b^2+t)(c^2+t)}=\zeta^2+\xi^2\frac{c^2}{b^2-c^2}(\zeta^2-\eta^2)$$
$$\tfrac{3}{2}M\int_0^\infty\frac{t\,dt}{D(a^2+t)(c^2+t)}=\zeta^2+\eta^2\frac{c^2}{a^2-c^2}(\zeta^2-\xi^2) \qquad (23)$$

Making $\xi=\eta=0$ in these equations and eliminating ζ we are again conducted to equation (8). Since t lies between 0 and $+\infty$ and it is understood that D denotes the positive root of

$$\sqrt{(a^2+t)(b^2+t)(c^2+t)}$$

it is clear that there can be no negative elements in either of these integrals, and they are, therefore, in all cases positive quantities. The quantities on the right hand side of equations (23) must therefore be essentially positive. As the semi-axes a, b, c are taken in order of magnitude the fractions

$$\frac{c^2}{b^2-c^2},\qquad\frac{c^2}{a^2-c^2}$$

are positive and consequently in order that the right hand members of (23) shall be positive it is necessary either that

$$\begin{matrix}\zeta>\xi\\ \zeta>\eta\end{matrix} \qquad (24)$$

or that,

$$\begin{aligned} \zeta^2 + \xi^2 &> \alpha^2 (\zeta^2 - \eta^2) \\ \zeta^2 + \eta^2 &> \beta^2 (\zeta^2 - \xi^2) \end{aligned} \tag{25}$$

where for brevity α^2, β^2 are written in place of

$$\frac{c^2}{b^2 - c^2} \text{ and } \frac{c^2}{a^2 - c^2}$$

Write also

$$\begin{aligned} A &= \tfrac{3}{2} M \int_0^\infty \frac{tdt}{D(b^2+t)(c^2+t)}, \\ B &= \tfrac{3}{2} M \int_0^\infty \frac{tdt}{D(a^2+t)(c^2+t)}, \end{aligned} \tag{26}$$

Before going further, we will transform these integrals in such a way that A and B shall be given in terms of certain elliptic functions. Let k and k' denote two complementary moduli; then writing

$$k = \frac{a^2 - b}{a^2 - c^2} \tag{27}$$

we have also

$$k' = \frac{b^2 - c^2}{a^2 - c^2} \tag{28}$$

denote by x the amplitude of an elliptic integral

$$\theta = \int \frac{dX}{(\Delta k, X)}$$

also write

$$t = c^2 \frac{\frac{a^2 - c^2}{c^2} - x^2}{a^2}. \qquad \begin{pmatrix} x = 0 & \text{for } t = \infty \\ x = \infty & \text{for } t = 0 \end{pmatrix}$$

We have now

$$\begin{aligned} a^2 + t &= (a^2 - c^2) \frac{x^2 + 1}{x^2} \\ b^2 + t &= \frac{(b^2 - c^2) x^2 + (a^2 - c^2)}{x^2} \\ c^2 + t &= \frac{a^2 - c^2}{x^2} \\ dt &= -\frac{2(a^2 - c^2)}{x^2} dx \end{aligned} \tag{30}$$

Substitution of these in the expressions for A and B gives

$$A = G\int_0^\infty \frac{x^2\,dx}{(1+k'^2x^2)^{\frac{3}{2}}(x^2+1)^{\frac{1}{2}}} - H\int_0^\infty \frac{x^2\,dx}{(1+k'^2x^2)^{\frac{3}{2}}(x^2+1)^{\frac{1}{2}}},$$

$$B = G\int_0^\infty \frac{x^2\,dx}{(x+1)^{\frac{3}{2}}(1+k'^2x^2)^{\frac{1}{2}}} - H\int_0^\infty \frac{x^2\,dx}{(1+x^2)^{\frac{3}{2}}(1+k'^2x^2)^{\frac{1}{2}}}, \quad (31)$$

where

$$G = \tfrac{3}{2}M\frac{2}{(a^2-c^2)^{\frac{3}{2}}},$$

$$H = \tfrac{3}{2}M\frac{2c^2}{(a^2-c^2)^{\frac{5}{2}}}. \quad (32)$$

Transforming again by means of the relation

$$x = \text{tan. } X$$

we have

$$A = G\int_0^{\frac{\pi}{2}}\left(\frac{1}{\Delta^2(k,X)} - 1\right)\frac{dX}{k^2\Delta(k,X,)} - H\int_0^{\frac{\pi}{2}}\frac{\text{sin.}^2 X\,dX}{\text{cos.}^2 X\,\Delta^3(k,X)}$$

$$B = G\int_0^{\frac{\pi}{2}}\frac{\text{sin.}^2 X\,dX}{\Delta(k,X)} - H\int_0^{\frac{\pi}{2}}\frac{\text{sin.}^2 X\,dX}{\text{cos.}^2 X\,\Delta(k,X)} \quad (33)$$

and finally,

$$A = G\int_0^{\frac{\pi}{2}}\left(\frac{1}{dn^2\theta} - \right)d\theta - H\int_0^{\frac{\pi}{2}}\frac{cn^2\theta}{dn^2\theta}\cdot\frac{su^2\theta}{cn^2\theta}\cdot d\theta,$$

$$B = G\int_0^{\frac{\pi}{2}} sn^2\,\theta\,d\theta \qquad - H\int_0^{\frac{\pi}{2}} cn^2\theta\cdot\frac{sn^2\theta}{cu^2\theta}. \quad (34)$$

Still further transformation would enable us to obtain values for A and B depending upon the θ-function, but it is not worth while to continue the process any further.

Resume now equations (23); these we see may be written in the form

$$\begin{aligned} \xi^2 - \alpha^2\eta^2 + [(1+\alpha^2)\zeta^2 - A] &= 0 \\ -\beta^2\xi^2 + \eta^2 + [(1+\beta^2)\zeta^2 - B] &= 0 \end{aligned} \quad (35)$$

Solving for ξ^2 and η^2 gives us

$$\xi^2 = \frac{(1 + 2\,\alpha^2 + \alpha^2\,\beta^2)\,\zeta^2 - A + \alpha^2\,B)}{\alpha^2\,\beta^2 - 1} \qquad (36)$$

$$\eta^2 = \frac{(1 + 2\,\beta^2 + \alpha^2\,\beta^2)\,\zeta^2 - B + \beta^2\,A)}{\alpha^2\,\beta^2 - 1}$$

The coefficients of ζ^2 in each of these equations is always positive, and the second terms of the numerators are always positive, but the entire numerator in each case, as also the common denominator, may be either positive or negative. If given values of α and β make $\alpha^2\,\beta^2 < 1$ the denominator will be negative, and it will then be necessary to choose for ζ a value which will make the numerator of each of these fractions also negative. If $\alpha^2\,\beta^2 > 1$ the common denominator of the fractions is positive, and ζ must be so chosen that the numerators shall also be positive. Each of these determinations of ζ give positive values for ξ^2 and η^2. It is clear now that the quantities α, β, ζ cannot be chosen arbitrarily, but that if the first two of these are given the third must be determined so as to satisfy the conditions of making ξ^2 and η^2 positive. It may be noticed here that if

$$\alpha^2\,\beta^2 < 1$$

equations (36) give positive va'ues of ξ^2 and η^2 by assuming $\zeta = 0$, or, the ellipsoid of three unequal axes is a possible figure of equilibrium in the case when the fluid rotates about the two principal axes, provided

$$\frac{c^2}{(b^2 - c^2)\,(a^2 - c^2)} < 1$$

or, by simple reductions

$$a^2 + b^2 - \frac{a^2\,b^2}{c^2} < 0$$

We can make either ξ or η equal zero, and equilibrium will be possible by properly determining α and β.

Take now the case when $\alpha^2\,\beta^2 - 1 < 0$, and determine the values of ζ^2 (other than zero), which will make ξ^2 and η^2 positive. Write the first of equations (36) in the form

$$\xi^2 = \frac{\zeta^2 - \dfrac{A + \alpha^2\,B}{1 + 2\,\alpha^2 + \alpha^2\beta^2}}{\dfrac{\alpha^2\beta^2 - 1}{1 + 2\,\alpha^2 + \alpha^2\beta^2}};$$

As the denominator in this is negative the numerator must also be

negative, and, therefore, for the determination of ξ^2 positive; when $\alpha^2\beta^2-1<0$ we have

$$\zeta^2 < \frac{A+\alpha^2 B}{1+2\alpha^2+\alpha^2\beta^2}$$

Similarly, for η^2 positive we must have

$$\zeta^2 < \frac{B+\beta^2 A}{1+2\beta^2+\alpha^2\beta^2}$$

For both ξ^2 and η^2 positive we have to determine ζ in such a way that both of these inequalities shall be satisfied. Now assume

$$\alpha^2\beta^2 - 1 < 0$$

The numerators in equations (36) must now be positive, and we must have

$$\zeta^2 < \frac{A+\alpha^2 B}{1+2\alpha^2+\alpha^2\beta^2} \text{ for } \xi^2 \text{ positive,}$$

$$\zeta^2 < \frac{B+\beta^2 A}{1+2\beta^2+\alpha^2\beta^2} \text{ for } \eta^2 \text{ positive.}$$

Finally, assume

$$\alpha^2\beta^2 - 1 = 0;$$

this obviously requires that

$$\zeta^2 = \frac{A+\alpha^2 B}{1+2\alpha^2+\alpha^2\beta^2} \text{ for } \xi^2 \text{ positive,}$$

$$\zeta^2 = \frac{B+\beta^2 A}{1+2\beta^2+\alpha^2\beta^2} \text{ for } \eta^2 \text{ positive.}$$

It is clear from these last two equations that *any* values of α and β which satisfy $\alpha^2\beta^2 - 1 = 0$ will not answer, but only such as shall make

$$\frac{A+\alpha^2 B}{1+2\alpha^2+\alpha^2\beta^2} = \frac{B+\beta^2 A}{1+2\beta^2+\alpha^2\beta^2}$$

Revert for a moment to equations (5), which correspond to rotation round the axis c. Combine the first and third of these and also the second and third, in order to eliminate k. We have

$$\zeta_1^2 \frac{a_1^2}{a_1^2-c_1^2} = \frac{2}{3} M\int_0^\infty \frac{t\,dt}{D(a_1^2+t)(c_1^2+t)}$$

$$\zeta_1^2 \frac{b_1^2}{b_1^2-c_1^2} = \frac{3}{2} M\int_0^\infty \frac{t\,dt}{D(b_1^2+t)(c_1^2+t)} \qquad (37)$$

or

$$\zeta^2(1+\beta_1^2) = \frac{3}{2} M \int_0^\infty \frac{t\,dt}{D(a_1^2+t)(c_1^2+t)}$$
$$\zeta^2(1+a_1^2) = \frac{3}{2} M \int_0^\infty \frac{t\,dt}{D(b_1^2+t)(c_1^2+t)} \qquad (38)$$

Where ζ_1, a_1, β_1 are written instead of ζ, a, β to denote that the rotation is around only one axis. Comparing these with (23), where a_1, β_1 may also be written instead of a, β, gives

$$(\zeta_1^2-\zeta^2)(1+a^2) = \xi^2 - a^2\eta^2$$
$$(\zeta_1^2-\zeta^2)(1+\beta^2) = \eta^2 - \beta^2\xi^2$$

We can clearly determine ξ, η, ζ in such a way that these equations shall be satisfied. The interpretation of this is simply that certain ellipsoids, which are figures of equilibrium when the rotation is around one principal axis, will also be figures of equilibrium when the rotation is around all three of the principal axes. The consideration of the case when the ellipsoids are of rotation need not be entered into, as the conditions for this case follow very simply from the formulæ already given for the more general case.

There is another way of attacking the general problem of the rotation of a fluid ellipsoid, which is much more general in its nature than the preceding. If we denote by u, v, w the component velocities of a particle of the fluid mass, whose position at any time is x, y, z, then these quantities are connected with the ξ, η, ζ of the preceding pages by the relatives

$$u = z\eta - y\zeta$$
$$v = x\zeta - z\xi \qquad (39)$$
$$w = y\xi - x\eta$$

and, as is well known from the principles of theoretical mechanics, consequently ξ, η, ζ denote the velocities which the ellipsoid would have if rotating as a rigid body. If the fluid, however, have a motion relatively to the ellipsoid, these quantities ξ, η, ζ are increased by certain other components, which call

$$\Xi, H, Z$$

Then, if the new components of the rotation of the ellipsoid about its axes are denoted by p, q, r, we have

$$\begin{aligned} p &= \xi + \Xi, \\ q &= \eta + H, \\ r &= \zeta + Z. \end{aligned} \tag{40}$$

And writing α, β, γ the component relative velocities of the particle

$$\begin{aligned} \alpha &= u + yr - zq, \\ \beta &= v + zp - xr, \\ \gamma &= w + xq - yp. \end{aligned} \tag{41}$$

By the introduction of the new velocities Ξ, H, Z we have now to write for u, v, w the expressions

$$\begin{aligned} u &= z\left(\eta + \frac{c^2-a^2}{c^2+a^2}\,H\right) + y\left(-\zeta + \frac{a^2-b^2}{a^2+b^2}\,Z\right) \\ v &= x\left(\zeta + \frac{a^2-b^2}{a^2+b^2}\,Z\right) + z\left(-\xi + \frac{b^2-c^2}{b^2+c^2}\,\Xi\right) \\ w &= y\left(\xi + \frac{b^2-c^2}{b^2+c^2}\,\Xi\right) + x\left(-\eta + \frac{c^2-a^2}{c^2+a^2}\,H\right) \end{aligned} \tag{42}$$

and consequently by substitution in (41)

$$\begin{aligned} \alpha &= 2\,a^2\left\{\frac{Z\,y}{a^2+b^2} - \frac{H\,z}{c^2+a^2}\right\} \\ \beta &= 2\,b^2\left\{\frac{\Xi\,z}{b^2+c^2} - \frac{Z\,x}{a^2+b^2}\right\} \\ \gamma &= 2\,c^2\left\{\frac{H\,x}{c^2+a^2} - \frac{\Xi\,y}{b^2+c^2}\right\} \end{aligned} \tag{43}$$

Multiplying these by x, y, z, respectively, and dividing by a^2, b^2, c^2, we have, on addition,

$$\frac{\alpha x}{a^2} + \frac{\beta y}{b^2} + \frac{\gamma z}{c^2} = 0 \tag{44}$$

and this expresses the fact that a particle which at any time lies on a given ellipsoid will throughout the motion lie either on this ellipsoid or on one similar to it. This is similar to one of the properties of the motion of a fluid particle in case a solid ellipsoid rotates in an infinite mass of fluid, viz. (*American Journal of Mathematics*, vol. 2, page 271), that the co-ordinates of a fluid particle are always expressible as functions of the parameter of the ellipsoid upon which it lies, which is confocal to the given ellipsoid. Our problem being now one in ordinary hydrodynamics, we can employ the equations of hydrodynamics for its further elucidation. It will not be necessary here to enter into a discussion of how the equations of motion are obtained in

the case of moving axes, and I shall merely write the equations at once. They may be found in Riemann's celebrated paper, "*über die Bewegung eines flüssigen gleichartigen Ellipsoides*," though not in the form given here. Denoting by p the fluid pressure, by ρ the constant density, and by V the potential of applied forces, we have

$$\begin{aligned}
&\frac{1}{\rho}\frac{dp}{dx} + \frac{d\,V}{dx} + w\,q - v\,r + \alpha\frac{du}{dx} + \beta\frac{du}{dy} + \gamma\frac{du}{dz} + \frac{du}{dt} = 0\\
&\frac{1}{\rho}\frac{dp}{dy} + \frac{d\,V}{dy} + u\,r - w\,p + \alpha\frac{dv}{dx} + \beta\frac{dv}{dy} + \gamma\frac{dv}{dz} + \frac{dv}{dt} = 0 \qquad (45)\\
&\frac{1}{\rho}\frac{dp}{dz} + \frac{d\,V}{dz} + v\,p - u\,q + \alpha\frac{dw}{dx} + \beta\frac{dw}{dy} + \gamma\frac{dw}{dz} + \frac{dw}{dt} = 0
\end{aligned}$$

If, as in Riemann's case, we assume that the only forces acting are those due to the mutual attraction of the particles of the fluid ellipsoid, we have

$$\frac{d\,V}{dx} = A\,x, \text{ etc.,} \qquad (46)$$

where

$$\begin{aligned}
A &= \frac{3}{2}\,M\int_0^\infty \frac{d\lambda}{(a^2+\lambda)N},\\
B &= \frac{3}{2}\,M\int_0^\infty \frac{d\lambda}{(b^2+\lambda)N}, \qquad (47)\\
C &= \frac{3}{2}\,M\int_0^\infty \frac{d\lambda}{(c^2+\lambda)N},
\end{aligned}$$

and

$$N = \sqrt{(a^2+\lambda)\,(b^2+\lambda)\,(c^2+\lambda)}$$

The values of these quantities are given in the article above referred to in the *American Journal of Mathematics*. Before going further observe that, no external forces acting, if we denote by $\omega_1\ \omega_2\ \omega_3$ the components of angular momentum, we have from mechanics

$$\begin{aligned}
&\frac{d\omega_1}{dt} - \omega_2\,r + \omega_3\,q = 0\\
&\frac{d\omega_2}{dt} - \omega_2\,p + \omega_1\,r = 0, \qquad (48)\\
&\frac{d\,\omega_3}{dt} - \omega_1\,q + \omega_2\,p = 0;
\end{aligned}$$

and since

$$\begin{aligned} \omega_1 &= \Sigma m\,(wy - vz), \\ \omega_2 &= \Sigma m\,(uz - wx), \\ \omega_3 &= \Sigma m\,(vx - uy), \end{aligned} \tag{49}$$

we can readily find

$$\begin{aligned} \omega_1 &= \frac{M}{5}\left\{\frac{(b^2-c^2)^2}{b^2+c^2}\,\Xi + (b^2+c^2)\,\xi\right\} \\ \omega_2 &= \frac{M}{5}\left\{\frac{(c^2-a^2)^2}{c^2+a^2}\,H + (c^2+a^2)\,\eta\right\} \\ \omega_3 &= \frac{M}{5}\left\{\frac{(a^2-b^2)^2}{a^2+b^2}\,Z + (a^2+b^2)\,\zeta\right\} \end{aligned} \tag{50}$$

and (47) now become

$$\left\{\frac{(b^2-c^2)^2}{b^2+c^2}\,\frac{d\Xi}{dt} + (b^2+c^2)\,\frac{d\xi}{dt}\right\} + \left\{\frac{(a^2-b^2)^2}{a^2+b^2}\,Z + (a^2+b^2)\,\zeta\right\} q - \left\{\frac{(c^2-a^2)^2}{c^2+a^2}\,H + (c^2+a^2)\,\eta\right\} r = 0, \text{ etc.} \tag{51}$$

The other two equations being easily written down by merely advancing the letters.

Eliminating the pressure from equations (45), in the usual manner, and substituting for u, v, w their values, we have

$$\begin{aligned} \frac{1}{a^2}\,\frac{d\xi}{dt} &= 2\left\{\frac{Z\,\eta}{a^2+b^2} - \frac{H\,\zeta}{a^2+c^2}\right\}, \\ \frac{1}{b^2}\,\frac{d\eta}{dt} &= 2\left\{\frac{\Xi\,\zeta}{b^2+c^2} + \frac{Z\,\xi}{a^2+b^2}\right\}, \\ \frac{1}{c^2}\,\frac{d\zeta}{dt} &= 2\left\{\frac{H\,\xi}{c^2+a^2} - \frac{\Xi\,\eta}{b^2+c^2}\right\}; \end{aligned} \tag{52}$$

multiplying these by ξ, η, ζ, respectively, adding and integrating, we have

$$\frac{\xi^2}{C_1\,a^2} + \frac{\eta^2}{C_1\,b^2} + \frac{\zeta^2}{C_1\,c^2} = 1 \tag{53}$$

where C_1 is a constant. Substituting in (45) the values of the different quantities therein contained, we have, on performing some complicated reductions:

$$\frac{1}{\rho}\,\frac{dp}{dx} + \left\{A + \frac{4\,c^2\,(c^2-a^2)}{(c^2+a^2)^2}\,H^2 - \left(\frac{c^2-a^2}{c^2+a^2} = \eta\right)^2 - \frac{4\,b^2\,(a^2-b^2)}{(a^2+b^2)^2}\,Z^2 - \left(\frac{a^2-b^2}{a^2+b^2} + \zeta\right)^2\right\} x = 0, \text{ etc.} \tag{54}$$

The other equations are readily written down. The coefficients of y and z in the first of (54) vanish by virtue of (51). These may all be written briefly, as

$$\begin{aligned} \frac{1}{\rho}\frac{dp}{dx} + Lx &= 0 \\ \frac{1}{\rho}\frac{dp}{dy} + My &= 0 \\ \frac{1}{\rho}\frac{dp}{dz} + Nz &= 0 \end{aligned} \tag{55}$$

from which

$$\frac{p}{\rho} + \tfrac{1}{2}(Lx^2 + My^2 + Nz^2) = \text{const.} \tag{56}$$

The surfaces of equal pressure are thus

$$Lx^2 + My^2 + Nz^2 = \text{const.}$$

It does not seem possible in this case to have constant values for L, M, N which shall be proportional to

$$\frac{1}{a^2}, \quad \frac{1}{b^2}, \quad \frac{1}{c^2}.$$

A further investigation would make it necessary to introduce functions of a higher order than elliptic, so I shall not, at present, attempt to go further in this interesting and rather curious problem.

It was my intention to add here a note on the motion of the fluid mass when the rotation is around the mean axis of the ellipsoid, but after having written out a portion of the work I discovered that that particular case has been fully worked out, in a most elegant manner, by Mr. A. G. Greenhill, in Vol. III of the Proceedings of the Cambridge Philosophical Society; I take pleasure, therefore, in referring the reader to that source for further information, which is there given in a much better manner than I could possibly present it. I trust that Mr. Greenhill may see fit at some future time to take up the more general problem of which I have here given a brief account.

Washington, D. C., Sept. 28, 1880.

A NEWLY DISCOVERED PROPERTY OF THE ELLIPSE, AND ITS APPLICATION TO THE "OVAL CHUCK."

By FRANK M. LEAVITT.

In studying to devise a machine for a certain purpose, the writer stumbled upon a mathematical property of the ellipse which he thinks to be not devoid of interest, on account of its apparently not having been noticed in any published treatment of the ellipse, and also on account of its practical utility for the purpose below mentioned.

In turning an ellipse on a lathe provided with an "oval chuck" the disadvantage is met with that at only four points, viz., at the extremities of the major and minor axes, is the surface of the work in a position normal to the cutting tool, half of the time the upper face of the latter being at an acute angle with the tangent to the ellipse at the point of cutting, whereby the tendency is to spring the tool away from its work, and during the remainder of the time, the angle formed being obtuse, the pressure tends to spring the tool inward, with the liability of making too deep a cut.

A similar state of things exists when a blank of sheet metal is being trimmed in an "oval chuck," and it is in this case so serious an obstacle as to make it totally impossible to obtain a satisfactory result.

It was while studying for a remedy in this latter case that the following property was noticed:

If an indefinite line be drawn through the centre of an ellipse, and if through a point on this line situated at a constant distance from the point of intersection with the ellipse (and outside the latter) a line be drawn making with the transverse axis of the ellipse an angle equal to the angle made with the same by the line drawn through the centre, the portion of the prolongation of the line so drawn included between its point of intersection with the line through the centre of the ellipse and a normal to the latter at its intersected point, will be of a constant length.

To make this clear by Fig. 1, draw any line through the centre, as $O\ D$. At the constant distance $A\ D = C$ draw through the point D a line $M\ D\ E$, making the angle $D\ M\ O = D\ O\ M$. From the point A draw the normal $A\ E$. Then will the distance $E\ D$, included

between the normal and the line $O\,D$ be constant for all positions, in the same ellipse, of the line $O\,D$.

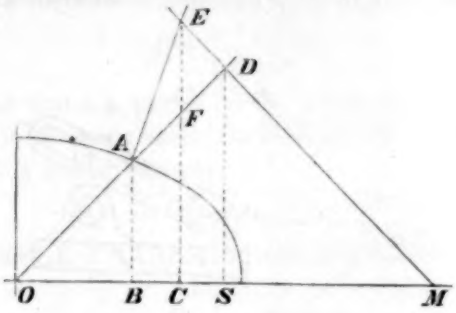


Fig. 1.

This may be proved as follows:

Let r be the *radius vector* $O\,A$ of the point of intersection A, a the angle $A\,O\,B = E\,M\,O$, x'' and y'' the co-ordinates of the point A, the origin of co-ordinates being at the centre of the ellipse, $\varphi_{,}$ and $y_{,}$ the co-ordinates of the point E, and a and b respectively the semi-transverse and semi-conjugate diameters of the ellipse. Let $E\,D = R$

We have
$$x_{,} = \cos.\ a\,(r + c - R)$$
$$y_{,} = \sin.\ a\,(r + c + R)$$

also,
$$x'' = r\cos.\ a$$
$$y'' = r\sin.\ a$$

which values, substituted in the equation of a normal to the ellipse,
$$(y - y'')\,b^2\,x'' = (x - x'')\,a^2\,y''$$
gives after reducing
$$R = \frac{a^2 - b^2}{a^2 + b^2}\,c.$$

Hence R is constant for each ellipse, and its value depends on the values of the major and minor axes of the same, multiplied by the constant c, and varies from $R = 0$ when $a = b$, or in the case of a circle, to $R = c$ when $b = 0$.

The manner in which this principle may be applied to a lathe furnished with an "oval chuck" is illustrated by the skeleton drawing Fig. 2, which is lettered similarly to Fig. 1.

The slotted arm $A\,E$ swings freely on the pivot A, which is fixed to the carriage of the lathe, and to this arm is fastened the cutting tool t by a proper tool post not shown in the sketch. The tool must

be so placed that its cutting edge is in line with the centre of motion A, of the arm $A\,E$, and of course enough in front of the pivot on which the arm vibrates as not to allow the latter to interfere with the work.

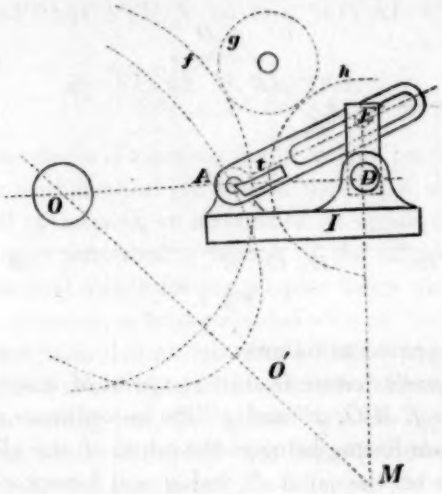


Fig. 2.

On the lathe carriage, at any convenient distance from the centre of motion A, is a rotating shaft D, which is geared in some way with the main spindle, O, of the lathe, so as to make two revolutions to the latter's one, and in the same direction. This shaft D is provided with a crank, $D\,E$, the crank-pin of which slides in the slot in the arm $A\,E$, and is so arranged as to be adjustable to any desired distance from the centre of the shaft.

When the transverse axis of the ellipse to be turned coincides with the line $O\,A\,D$ the crank $E\,D$ must be on its inner centre, that is, with its crank-pin in the line $O\,A\,D$, and between O and D. Then, since the shaft D has twice the angular velocity of the spindle O, it follows that at all times the angle $A\,D\,E$ formed by the crank with the line $O\,D$ will be twice as great as that formed by the transverse axis with the line $O\,D$, or $A\,D\,E = 2\,D\,O\,M$, a condition required in our proposition. Also, the fixed distance $A\,D$ represents the constant c, the crank $D\,E$ being the constant R. It therefore follows, from the conditions above set forth, that in all positions of the chuck the arm $A\,E$, and consequently the tool t, will be in a normal position to the periphery of the ellipse at the point of cutting, which is the condition sought for.

The mechanism may be adapted to the turning of ellipses of different eccentricity by simply adjusting the distance of the crank pin from the centre of the shaft D so that its value will be

$$R = \frac{a_2 - b_2}{a_2 + b_2} c.$$

It is evident that if a pair of rotary cutters be substituted for the turning tool, in trimming sheet metal blanks, the required result will be obtained in a similar manner.

A SIMPLE TRANSMISSION DYNAMOMETER.

By Elihu Thomson.

While engaged in the work of constructing and testing dynamo-electric machines of various sizes and capacities, the need was felt of a simple instrument, by means of which a measurement of power transmitted to a machine could be readily obtained. To supply this need, the dynamometer which forms the subject of this paper, was devised. It is a modification of the dynamometer which, I believe, was invented by Herr von Hefner-Altenech, and used by Dr. J. Hopkinson in his tests of Siemens' dynamo-electric machines.

Fig. 1

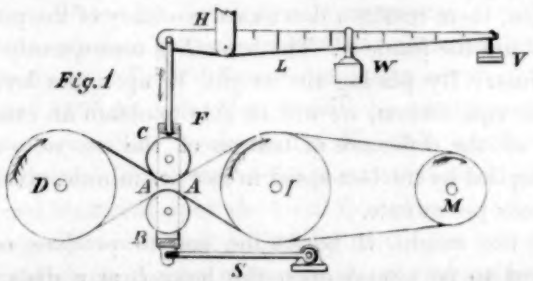


Fig. 1 represents a side elevation of the essential parts and their relations to one another. D is the driving pulley, from which power is conveyed to the driven pulley M by a belt. The pulley M, in my experiments, was upon the shaft of the dynamo-electric machine which consumed the transmitted power. The relative sizes of the pulleys D and M is immaterial. Between them, and distant from D its own diameter, is mounted an idle pulley I, of the same diameter as that of D. Between the driving pulley D and the idle pulley I are

two small idle pulleys, *B C*, mounted to run freely in a movable frame, *F*. The pulleys *B C* are placed at such a distance apart that the angles *A A*, formed by lines of the belt leaving *D* and *I*, shall be each 60°. The frame *F*, supporting the pulleys *B C*, is hung upon one extremity of a horizontal lever, *L*, whose fulcrum is at *H*. The frame *F* and pulleys *B C* are free to move in a vertical direction through a small range, being suitably guided, as at *S*. The lever *L* is provided with a sliding weight, *W*, and has divisions marked upon it equal to, or fractions of, the distance from the fulcrum *H* to the points of attachment of the frame *F* to the lever *L*.

The weight *W* is first removed, and the lever *L* and counterpoise *V* made to exactly balance the frame *F*. This adjustment is made when the parts are free to move, and once made need not be repeated. It matters not what may be the tension of the belt used, the equilibrium will remain undisturbed, because the strains are counterbalanced upon the pulleys *B* and *C*. Let now rotary motion be imparted, as shown by the arrows, and all parts be assumed to run without friction or resistance; the equilibrium of the lever and frame will not be disturbed. Further, let there be a consumption of power in turning the pulley *M*. In this case the lower side of the belt will become more tense than the upper side, and in consequence, the pulley *B* having to support this added tension, and *C* being relieved of part of the tension, there results a downward tendency of the pulley *B*, followed by *C* and the frame *F*. The lever *L* is consequently thrown out of equilibrium. By placing the weight *W* upon the lever *L*, so as to restore the equilibrium, we will be able to obtain an exact measure, in pounds, of the difference of tension of the two sides of the belt, which, multiplied by the belt speed in feet per minute, gives the power in foot-pounds per minute.

Thus, if the weight *W* be 33 lbs. and to produce equilibrium, it is required to be placed upon the lever *L* at a distance from *H* equal to that of the frame *F* on the other side, then the tendency of the frame *F* to move downwards is 33 lbs. But when the angles *A A* equal 60° each, the downward tendency of the frame *F* equals the difference of tension of the two sides of the belt, or the difference in longitudinal strains of the driving side and loose side. To determine the belt speed per minute it is of course only necessary to know the circumference in feet and number of revolutions of either of the pulleys *D*, *I* or *M*, and multiply these quantities together. In the case

assumed let the product, or belt speed, be 1000 feet, which, multiplied by the tension difference, 33 lbs., is 33,000, or one horse-power.

Fig. 2

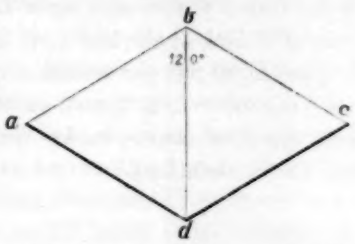


Fig. 2 is intended to elucidate the effect produced upon the frame F by the increase of the tension of the driving side of the belt, and to show that the downward tendency of said frame is a measure of the difference of longitudinal strain of the tight and loose sides of the belt. Since the strains upon the pulleys B and C, due merely to the tightness of the belt, irrespectively of its function in conveying power, are equal upon each, these strains neutralize each other, and may therefore be neglected. In Fig. 2 let $a\ b$ and $b\ c$ represent the differences of belt strain due to power transmission, on the portions of belt upon each side of the frame F; that is, $a\ b$ represents the difference of strain of two portions of the belt, one passing tangentially from the pulley D to the pulley C, and the other portion passing tangentially from D to B. Similarly, $b\ c$ represents the difference of strain of those portions passing tangentially from the pulley I to B and C respectively. These differences of strain act upon the pulley B at an angle of 120° to each other, as will be seen from the direction taken by the belt. The resultant, $b\ d$, Fig. 2, is equal to $a\ b$ or $b\ c$ and is downward. This resultant is counterbalanced by the sliding weight W and measured upon the lever L used as a steelyard.

When properly constructed, so that the parts have sufficient freedom of motion, this dynamometer is capable of showing quite small variations of power consumed, and it has the advantage that the measurements are taken directly from the driving belt and not from intervening apparatus involving considerable friction. When the upper side of the belt is the tight or driving side, suitable modifications can be made in the arrangement of parts, and will readily suggest themselves. The dynamometer which I have used has about the following dimensions: Pulley $D = 32$ in. diam.; $I = 32$ in. diam.; distance between D and $I = 32$ in.; diameter of pulleys B and $C = 8$ in.;

distance from centre to centre of B and $C = 10$ in.; length of the lever $L = 80$ in.; the support, or fulcrum, H is 10 in. from the point of attachment of the frame F, and the lever L is divided on the long arm into divisions of 5 inches, marked 1, 2, 3, etc.; the weight W is 33 lbs., and belt speed 2000 feet per minute.

In this case the numbers 1, 2, 3, etc., on the lever L read horse-powers. The belt speed, of course, varies within certain limits, and allowance is made for its variations.

METHODS FOR JUDGING OF THE WHOLESOMENESS OF DRINKING WATER.*

By Reuben Haines.

Many years ago the usual way to ascertain the wholesomeness of drinking water was to discover what mineral impurities were present. The water was therefore evaporated to dryness, and a more or less complete analysis was made of the solid mineral substance left, as is done with mineral-spring waters. Little attention was given to the organic matter, except when present in very large amounts, as in marsh water, etc. Occasionally, even now, we read of some one making tests for mineral impurities in a suspected well water, but omitting any test for the organic matter. Such analyses were exceedingly troublesome; and, after all, it is very doubtful whether they were of much value—in many cases perhaps of no value whatever, in ascertaining the wholesomeness of ordinary drinking water. Of course, the detection of iron and of sulphate of lime and magnesia, in this way, was of some importance, for waters containing considerable amounts of these substances should be considered unwholesome for daily use, in health. But we really have no reason at all for supposing that such mineral substances as silica, alumina, potash and soda, as they occur in any, but very rare cases, have any influence whatever on health. Moreover, waters which are free from much mineral salts may often be very unwholesome for other reasons not discoverable at all in this way. This sort of analysis has therefore been entirely discarded by chemists conversant with recent sanitary experience, except in selecting a new source of water

* Abstracts of lectures delivered before the Franklin Institute, December, 1880, in which additional original matter has been introduced.

supply for a city, which involves other than sanitary interests as well.

In the preceding lecture it was shown that by far the most important element in sanitary investigations of water, is the organic matter contained in it, either in the form of minute suspended particles or in actual solution. It was shown that the purest rain and spring waters contain a minute amount of organic matter, but that rivers, streams, and shallow wells in populous districts, contain much larger proportions of it. It has long been known that waters, the sources of which originate in populous districts, were often the apparent cause of disease.

These facts have been for many years recognized by chemists, and it has therefore been their endeavor to devise methods for finding the exact amount and also the nature of this organic material. Let us now briefly review the advances which have been made in this direction.

The earliest method used for this purpose was what is known as the "ignition" process. It consisted in evaporating a measured quantity of water to dryness at a temperature which varied with different chemists, and weighing the residue. This residue was then exposed in a platinum dish to a sufficient heat to burn away all the organic matter. On cooling, the weight was again taken, and the difference was called organic matter. It was very simple, and easily performed, and was extensively practiced. It has been shown, however, to give very erroneous results in a large number of cases, especially with hard waters, and well waters containing considerable nitrate. There are numerous chemical objections to it which render it entirely fallacious, but it will not be proper on the present occasion to enter into much chemical detail. We may say, however, that any carbonates of lime, etc., will, by the heat necessary to burn away the organic matter, partially lose their carbonic acid, ammoniacal salts will be volatilized, nitrates will be converted into carbonates by the carbon of the organic matter, these and other salts will lose water of crystallization, and if much chloride of sodium is present, in contact with carbon, hydrochloric acid will be volatilized, the fumes of which are often perceptible in thus treating the residue of a highly polluted water. Moreover, it is frequently difficult to get rid of the last traces of unconsumed carbon without raising the intensity of the heat so as to render the loss of mineral salts positively certain. In fact, we can never know what interchanges may take place among the materials of the residue when heated to faint redness. Various efforts were made to avoid this, or to replace the loss. Carbonate of soda was added during the first evaporation, but it has

been shown that by this means a part of the organic matter was liable to be destroyed before the first weight was taken. Carbonate of ammonia, or carbonic acid water was added to the residue after being heated, so as to restore the lost carbonic acid, but while this confessedly replaces only a part of the loss, it has also been shown that the weight of the residue is frequently increased in a curious and irregular manner by this means, so as finally to become sometimes considerably greater than it was before being heated at all.

Prof. Wm. Ripley Nichols finds this method, with the employment of aqueous carbonic acid, of some utility for the relative comparison of the very soft waters of many New England streams. In these cases the loss appears to represent chiefly organic matter, and is recorded as "organic and volatile matter," which is the only accurate designation for it. But the results probably can never be, constantly, very exact, and no reliance should be placed upon them to the exclusion of other tests. In the case of the majority of well waters Prof. Nichols considers this method valueless. It may frequently be useful, and as a qualitative test only, to heat the solid residue, and notice the odor, if any is given off. This will aid us in distinguishing animal from vegetable substances.

The unsatisfactory character of the "ignition" method led chemists to adopt what is known as the "permanganate" method. Of this there are numerous modifications, giving different results according to the practice of different chemists. They are all based on the same general principle, which is strikingly illustrated by the action of potassic permanganate on oxalic acid in solution. The magnificent color of the permanganate almost instantly disappears in a surprising manner. If we pour very rapidly, numerous bubbles of gas rise and burst at the surface, exactly as in a glass of soda water. Now, what happens here is, chemically, just as truly combustion, as the burning of coal in a fire, only the oxidation takes place in water instead of air. The permanganate is rich in oxygen, which it gives up very readily, and this combines with the oxalic acid to form carbonic acid and water, just as the oxygen of the air unites with the burning coal to form the same substances. The oxalic acid is destroyed and the resulting carbonic acid gas passes off in small bubbles. The permanganate also is destroyed, as is shown by the disappearance of color, and the hydrated oxide of manganese, which would otherwise settle in brown particles, is held in

solution by sulphuric acid, a little of which was previously added; forming the colorless manganese sulphate.

Now oxalic acid is only one of the many organic substances upon which potassic permanganate acts in the same way, in a greater or less degree. As long as there is organic substance in the liquid to be acted upon, the color of the permanganate will be destroyed, although, in some cases, very slowly; but as soon as this organic substance is exhausted the pink color will remain permanent in the liquid. We obtain in this way a sort of measure of the amount of organic substance. In the actual analysis the chemist takes a measured quantity of the sample of water and pours into it from a measuring-tube, called a burette, a solution of permanganate of known strength. This is a very imperfect description of the method, but it is sufficient for our purpose.

This method, with whatever modification it is used, does not really show how much organic matter is actually present, but only how much oxygen has been required by the substances which are capable of being oxidized in this way. German chemists are in the habit of reckoning five times the numbers obtained in the analysis as representing the total amount of "Organischer Substanz." This is, however, an arbitrary factor, and while it may have been tolerably accurate for some waters used as test-analyses, we have no proof at all that the calculation would be accurate in all other cases, and it is hence reduced to a mere guess.

There are many objections to this method which show it to be very unreliable. Different substances are acted upon in very different degrees by permanganate, and upon some that must frequently occur in polluted water there is no action at all. Hence the method cannot by any means be relied upon to give the absolute amount of organic substance. If nitrous acid, ammonia, hydrogen sulphide, or protoxide of iron are present in the water they will affect the permanganate in the same way as organic matter, and would be counted as such in the analysis. We must, therefore, find the amount of these substances in other ways and make a correction for them. It is also stated to be uncertain whether the action on ammonia is uniform, and if it is not, no accurate correction for the ammonia can be made. Dr. Frankland, while condemning this method as entirely unreliable for ascertaining the *quantity* of organic matter, admits that it may be a useful *qualitative* test. "Thus," he says, "if a clear and colorless water decolorizes much of the perman-

ganate solution the water ought to be rejected for domestic use, as being of doubtful quality." It has the advantage of being readily performed, as a qualitative test, in a short time, with few materials and no special apparatus, and is therefore useful on occasions when there is no opportunity for a regular analysis.

In the hands of any one chemist, its use as a quantitative method will, without doubt, give some valuable information as to the relative quality of different waters, if the test is always performed in the same manner. The degree of rapidity with which the oxidation takes place will probably give some idea as to the putrescible nature of the organic matter. It is thus that Dr. Tidy's periodical analyses of the metropolitan water of London, by the permanganate method, have not been without value.

In England and America both the methods I have described have been to a great extent abandoned, and two other methods have taken their place. These are Wanklyn's ammonia method, and Frankland's combustion method, which were devised and published at nearly the same time in 1867 and 1868. The Frankland process consists in evaporating a measured quantity of water to dryness and burning the residue in a combustion-tube on the same principle as that by which an organic analysis is made. The resulting gases instead of being immediately absorbed are measured in a delicate and complicated apparatus for gas analysis, and then separated by absorption. The gases resulting from the organic matter are chiefly carbonic acid and nitrogen, and are calculated as organic carbon and organic nitrogen. The gases are drawn out of the combustion-tube by means of a Sprengel vacuum pump, and upon the perfection of the vacuum produced, depends, in part, the reliability of the results.

The Wanklyn method, which is much more generally practiced, makes use of the potassic permanganate. A measured quantity of the water to be analyzed is put into a glass retort, to which is attached a condenser. A little carbonate of soda is dropped in through the stoppered orifice in the retort, and the water is distilled rapidly until no more ammonia is given off, and condensed with the steam. The distilled water is collected in flat-bottomed test-tubes of perfectly colorless glass. This ammonia, which is first distilled, is called free ammonia. It is that which is present, in the form of ammonia, either in the free state or in combination, in the water. A solution of potassic permanganate, with which a strong solution of caustic potash has been

mixed, is now poured into the retort, and the distillation continued until no more ammonia is perceived in the distilled water. The ammonia now found in the distillate is called "albuminoid ammonia," and is that which results from the decomposition of nitrogenous organic matter by the action of the permanganate solution. Hence it represents that organic matter, and forms a relative, more or less definite, measure of it. It is upon this peculiar action of a boiling, strongly alkaline solution of potassic permanganate that the method of Wanklyn is founded. The delicacy of the method depends upon the sensitiveness of the Nessler test for ammonia, which is one of the most delicate colorometric tests in the whole range of analytical chemistry, being capable of recognizing easily one part of ammonia in ten million parts of water, and distinguishing differences of one-third of this amount.

Let us now consider some of the defects of these two methods of analysis and appreciate what may be really learned by their use.

In the first place, by neither of them can we, with certainty, estimate the exact amount of organic matter actually present in water. For this purpose there is no method known; nor can these methods enable us to identify and separate the different kinds of organic substances that may be present. In fact, we know almost nothing as to their nature, except that there is a general impression that much of this polluting material is probably of an albuminoid character.

Frankland's method endeavors to estimate the exact quantity of organic matter, but, as will be seen by a candid examination of the essential defects of the process, there is at least a formidable array of probabilities against the possibility of its doing this.

Wanklyn, on the other hand, does not undertake to estimate the absolute quantity, but simply attempts to find a factor by which to make a tolerably accurate comparison of the relative purity or impurity of water. By this method we analyze a naturally good water, known beforehand to be wholesome by long experience and absence of any contaminating source, and the results obtained from this are then taken as a *standard* by which to compare other waters. The opinion is expressed by some chemists that this standard, although practically constant for any one locality, will be apt to vary considerably for different localities, even remote from the seaside.

In comparing the two methods we may say that both are philosophical in some points, and both unphilosophical in other ways.

That of Frankland seems theoretically better, because a combustion is made of the organic matter on precisely the same principle that is employed in the ultimate analysis of an organic compound. By this means the carbonaceous matter not nitrogenous is also estimated, which does not enter into the results of Wanklyn's method.

But Wanklyn's method is more philosophical, because it deals with the water itself, and not with merely the solid residue left after evaporating the water. We want to know what is contained in the water, or at least the properties of the water; but we do not necessarily need to know what is in the residue, for it is at best only indirect evidence, and what is shown by it may be only partially true of the water from which the residue came.

The value of Frankland's process depends on the assumption that what is contained in the residue fairly represents what is contained in the water itself, deducting of course the nitrates, which must be got rid of in conducting this method. This is really an assumption which Frankland has never clearly proved to be a fact, and which Wanklyn and others, including German authorities, claim is a mistake. It has been shown by German chemists that an appreciable amount of organic matter is lost during the evaporation of the water, especially when originally volatile matter is present. Moreover, we have no knowledge as to whether volatile products may not be formed during the evaporation at the boiling temperature. Frankland endeavors to prevent the latter result by the addition of sulphurous acid, taking advantage of its antiseptic properties. This has, however, been shown to be quite objectionable, causing the inevitable loss of part of the organic matter through the formation of gradually concentrating sulphuric acid. It is claimed that the further addition of sodium sulphite will not sufficiently neutralize this acid; but whether this is correct or not may not have been proved. Several other technical objections* have been advanced against the method, which it will be unnecessary to quote here. Finally, the chances of error, and the numerical corrections to be made are so numerous as to make this method quite complicated and difficult. It requires the chemist to be thoroughly skilled in the most delicate gas analysis, on account of the exceeding minuteness of the quantities to be measured, as compared with ordinary analysis. The apparatus is costly and fragile, and considerable time is required

* *Vide Jour. Chem. Soc., Chem. News*, etc.

for each analysis. Skilful chemists might not consider some of these as really serious objections, but they will certainly prevent the general adoption of this method by City and State Boards of Health for sanitary purposes.

This method endeavors, also, to determine the character of the organic matter by the proportionate relation of the organic nitrogen, to the organic carbon, this relation being found to be, by an average between wide limits, respectively, 1 : 11·9 for waters containing extract of peat, and 1 : 1·8 for sewage.

But Frankland has found that oxidation of peaty matter decreases the carbon, while oxidation of sewage decreases the organic nitrogen. "It is thus evident that the proportions of nitrogen to carbon in soluble vegetable and animal organic matters vary in opposite directions during oxidation—a fact which renders more difficult the decision as to whether the organic matter present in any given sample of water is of vegetable or animal origin."

Prof. Nichols quotes* from Sander: "Without a knowledge of the previous history of the water, the relative proportion (between carbon and nitrogen) is not available as a means of deciding as to the nature of the contamination; if, however, the previous history of a water is known, there is scarcely need of so particular an analysis in order to judge of its character." †

It has been shown that in the case of very pure waters the experimental error may often be greater than the total amount of organic material to be estimated, and that in the case of waters containing readily decomposable nitrogenous organic matter, together with a large excess of nitrates, the accuracy of the results may be more or less vitiated by the efforts to get rid of the latter. Mr. Wigner says that "supposing that the organic nitrogen yielded by the Frankland and Armstrong process were a positive quantity instead of a quantity needing a heavy correction for personal equation and for impurities in the chemicals used, yet the danger of error involved in the analysis, and the risk of contamination by atmospheric impurities, are in my opinion sufficient to prevent it from ever coming into general use; and unless generally used it is undesirable for reports which appeal to public sense and public understanding." ‡

* Prof. Nichols' paper in Buck's *Hygiene*, vol. 1, page 303.

† "Handbuch der öffentlichen Gesundheitspflege," p. 230.

‡ *Sanitary Record*, Oct. 19, 1877.

Wanklyn's method is also unsatisfactory and unphilosophical as a scientific quantitative method, because it assumes that most of the organic material usually found in drinking water is in its general character similar to animal and vegetable albumin. This is an assumption which no one has yet proved to be correct, and it is difficult to perceive how it can be proved until we know definitely what these specific materials are, which it is impossible to determine in the present state of our knowledge. Wanklyn found that pure albumin yielded by this method about two-thirds of its total nitrogen as ammonia, and that this proportion was quite constant. That this is also true of organic matter in water cannot at present be proved. He proposed at first to calculate the total organic matter as ten times the albuminoid ammonia, but this, he has since, evidently, and it should be said rightly, rejected as both unscientific, and really not necessary for the practical judgment of the sanitary character of water by his method.

Those who are familiar with the most recent sanitary experience realize that it is the *quality* rather than the *absolute quantity* of organic matter that is the most important factor in the sanitary judgment of a drinking water. A water which contains a large amount of one kind of organic substance may be much more wholesome, or far less unwholesome, than that which contains only a small amount of another kind. It is a matter of actual experience that a water, notwithstanding it contains a large amount of nitrogenous organic matter capable of yielding albuminoid ammonia, may be found to be practically wholesome, or at least may be drunk for a long period without apparently producing any injurious effects; while, on the other hand, a water which contains *even a minimum* of organic substance capable of yielding albuminoid ammonia may nevertheless contain or develop the *materies morbi* or unknown causal "something," of a specific disease.

While Wanklyn's ammonia method is certainly of very easy and expeditious performance, yet great caution is necessary in the formation of an opinion from the analytical results; and thus it may frequently happen that serious mistakes may be made through hasty conclusions from insufficient data. It is said very truly that a really very bad water will rarely, if ever, escape condemnation, and an exceedingly pure water will undoubtedly be shown to be pure, so far as this is possible by any chemical investigation. But by far the larger number of

well waters more especially lie between these extremes, and must take their place under the head of Doubtful Purity, and it is in the judgment of the latter that the analyst is liable to error, even to the extent of rendering an opinion diametrically the opposite of that of another chemist.

One of the precautions necessary to be taken in these, and in fact in all cases, is to avoid placing any *strict* reliance, for purposes of judgment, on the standards of purity which have been published in the treatise on Water Analysis by Wanklyn, and quoted in a number of recent works on Hygiene. It is impossible to lay down exact standards, or rules for judgment, which will hold good for all countries and all localities in any one country. Such "standards" are, as Professor Nichols observes, only of relative value, and different kinds of water cannot be judged by the same standard.*

We must, first of all, discover, by numerous and carefully selected analyses, what are the chemical characteristics of good wholesome water in any given locality. These data then form a standard of purity for all waters of one kind within that particular district. A general knowledge of the geological and mineralogical character of the soil and rock of that region is an important factor in such a standard. A knowledge of the chemical character of the ground-water of the district, entirely free from any artificial conditions, such as polluted soil, is necessary for judgment of the well waters of the same district.

As regards different kinds of waters we must distinguish between

I. Ground waters, which include shallow well waters.

II. Deep well waters, including artesian wells.

III. Surface waters, such as rivers, streams, lakes and ponds.

These three classes have essentially different characteristics, and one should not be compared with another without making proper allowances for these differences. It is thus incorrect to compare well waters near Philadelphia directly with the water of the Schuylkill river, as is sometimes done.

Upon reflection it will be readily understood that well waters are not commonly subjected to the oxidixing influences to which river waters are so freely exposed, such as direct sunshine, air in motion over the surface, and aeration due to falls and currents in the river. Some mineral salts from factory refuse, from coal mines, etc., have

* Prof. W. R. Nichols' paper on "Drinking Water and Public Water Supplies," in Dr. Buck's *Hygiene*, vol. 1, page 303.

possibly a modifying influence which is absent in the case of wells. Now there is a general feeling, among the medical profession and sanitarians, that organic matter which is more liable to rapid decomposition is more dangerous to health than more stable organic substances. In river waters there are greater chances for this decomposition to have been completed, leaving such substances as may be of the latter class in much greater proportion.

Hence a larger amount of organic matter will be allowable in river water in the condition used for drinking than in well waters, provided that the supply is taken at a sufficient distance from the places where polluting material enters the stream.

Another point of importance in forming an opinion on the wholesomeness of a surface water is the natural character of its source. A river water which originates in peat bogs, or the tributary streams of which pass through a peaty district, will contain extract of peat in solution throughout its whole course. These waters certainly should not be compared, without qualification, with river waters which do not come in contact with peat, but nevertheless yield on analysis an equivalent amount of albuminoid ammonia derived from sewage contamination.

Thus, for instance, the water of Lake Cochituate, one of the sources of supply for Boston, probably contains considerable extract of peat, or other "vegetable extractive matter," which is, so far as we know, perfectly harmless in drinking water. So, also, is this the case, I believe, with the water of Jamaica Pond, which also supplies a part of Boston. Now, the Schuylkill river water supplied to Germantown, and taken from the river at Flat Rock dam, pumped at the Roxborough Water Works of Philadelphia, gave, according to my own analysis, during the winter and summer of 1878, almost exactly the same results as Professor Nichols' analysis of the Cochituate and Jamaica Pond waters in 1873 and 1875, respectively, and with the same degree of variation at different times. But, while the analytical results are the same in both cases, a comparison of the general characters and sources of these waters convinces me that we cannot call the Germantown supply nearly so pure from objectionable organic matter as the Boston water. I think we may safely say that the Schuylkill contains no extract of peat, and the albuminoid ammonia undoubtedly comes from material which is far more objectionable. At times, also, since 1878, this albuminoid ammonia is as much as one-half greater

than the largest amount from the Cochituate water in 1873, as supplied at the Massachusetts Institute of Technology, and nearly twice as great as the average amount of the latter. At such times the water has a perceptibly disagreeable taste and a slight odor, and this occurs usually when the water in the river is very low from drought.

In general, it may be said to be very necessary to know the exact source of any water submitted for analysis, the physiographical and geological characteristics of the locality from which it comes, and the location of any sources of pollution, such as cesspools, privies, drains or sewers near the place of water supply. Whatever method of analysis is used, or in whatever way performed, the necessity of a knowledge of the previous history of the water is not diminished. Even with this knowledge, as is stated by Prof. Nichols, cases may arise in which an experienced chemist will be unable to give a decided opinion.

When the river water is pumped up into distributing reservoirs, the water from near the surface, and at the bottom of these reservoirs should be submitted to analysis, so as to locate more accurately any trouble which may exist.

Furthermore, attention should be especially called to the fact previously referred to in this paper, that it is probably not so much a question as to how much organic matter, *per se*, may be consumed without danger in our drinking water. This point does enter, it is true, into the consideration. But it is *mainly* a question as to whether there is any danger of the water being contaminated with fæcal discharges from human beings suffering from infectious disease. It has been found that water containing so large a proportion of organic matter as to be called "loaded" with it may be drunk with impunity by some persons or, at least, without any disastrous result being apparent for a long time; provided it does not also contain the "contagium" or unknown "something," whatever it may be, which will of itself develop specific disease. As soon as this "something" appears to be added by a previously diseased person an epidemic of this disease breaks out among those who consumed the water and who, until this time, remained apparently healthy.

Inasmuch as we have no means whatever of discovering the presence of this "contagium" because we know nothing of its character, any contamination with sewage is dangerous in proportion to its

amount, and to the nearness of the pollution in time and place. Some authorities in Holland were once asked how much organic matter was allowable in drinking water without danger, to which they replied that drinking water should be, like Cæsar's wife, above suspicion. It may be laid down as a positive rule that a suspicious water is always a dangerous water.

The extent of dilution of the sewage in a river with a large body of moving water of good quality is undoubtedly an important factor, but this may be entirely counterbalanced by the fact of the water supply being taken very near a large sewer.

Upon these considerations lies the importance of the estimation of the nitrates and nitrites in a drinking water. These salts are among the results of the decomposition of organic nitrogenous matter, and are hence an evidence of what was either previously contained in the water, or which became oxidized by filtration through soil or by other means of decomposition before it reached the water. The greater the amount of nitrates above the natural limit, the larger the amount of organic material which has hitherto undergone oxidation, and hence the greater the danger, in the case of wells, of the soil becoming saturated and clogged with organic substance until a part of it will escape filtration and pass unchanged into the water. Moreover, this part, which has escaped oxidation, may contain, for ought we know, the poison of a specific disease. Hence, it is important in order to form a correct opinion of the sanitary character of a well water, never to omit the proper tests for nitrates and nitrites, unless all the other quantitative tests concur in pronouncing the water pure. If any one of these gives a doubtful answer, the nitrates should always be tested for, and if more than traces are present, it will be best to make a quantitative estimation of them. It is true that nitrate may, probably, also result from reduction of the true ammonia, but this fact does not render the estimation any the less important, for this ammonia itself, under ordinary circumstances, results from the decomposition of the organic matter, and in shallow wells is usually regarded as evidence of pollution with urine.

We should remember, however, that deep wells may furnish a very pure water, containing very little organic matter, but large quantities of free ammonia, chlorides, and nitrates, all present in the same sample, which are derived from certain kinds of soil, such as the sand beds beneath the London clay and about 250 feet below the surface.*

* Dr. Cornelius B. Fox. "Sanitary Examinations," p. 140.

Mr. Ekin* considers it necessary to estimate the amount of nitrates and nitrites in every instance, and states that a small increase in their amount should materially influence the judgment to be given. He states that he has been forced to this conclusion by facts ascertained in the course of his somewhat wide experience in the analysis of about 2000 samples of water, many of which were directly connected with cases of typhoid fever.

The estimation of nitrates, etc., in a river water, however, has manifestly not the same significance which it possesses in the case of well-waters, on account of the superior influences effecting oxidation in the former, and the probable absorption of nitrates by aquatic plants. As regards *nitrites*, it is stated that delicate tests have not revealed their presence in the Thames river water.

In partial corroboration of the opinions of Mr. Ekin and Dr. Fox, as to the necessity of the estimation of nitrates, I will contribute a case in my own experience. I refer to the epidemic of typhoid fever in Spring alley, or Royal street, in the southernmost part of Germantown, which occurred last summer during the last week of July and first of August. There were upwards of forty cases, including four which proved fatal; and all, except one, were grouped in the immediate neighborhood of a well situated at the intersection of two narrow streets. This well, known as the Spring alley well, has had a wide reputation as a remarkably strong pure spring for, it is said, nearly a century. It is also said that typhoid fever never occurred in this locality before 1880. The well is only ten feet deep, the ground slopes down towards it from three sides, and a brick sewer passes within about ten feet of it, at about the same depth and having two badly choked up inlets directly opposite the well. An overflow drain connected the well directly with the sewer, *entering the latter near the bottom* at a short distance beyond the well. On the 5th of July a very heavy rain occurred, which deluged the vicinity of the well. As the sewer has, at this place, scarcely any fall it must have become suddenly clogged up with filth, and backwater must have occurred through the overflow drain directly into the well, polluting it, no doubt, to a very great degree. It was subsequently found by Dr. A. F. Müller, of Germantown, that a case of typhoid fever, probably imported from elsewhere, had occurred in a neighboring house about six weeks before the heavy

* "Potable Water. How to form a Judgment on the Suitableness of Water for Drinking Purposes" By Chas. Ekin, F.C.S. London: 1880.

rain, and that the drain from this house connected with the sewer above the well. There were also other circumstances probably contributing to the pollution of this well. Another well, frightfully foul, but in no way connected with the sewer, being on higher ground, and the sewer lying between the two wells, increased, no doubt, the malignity of the epidemic. All the cases of fever developed at nearly the same time. The exceptional one, before mentioned, which did not occur close to the well, but at a house two blocks distant, was a child in a family who had sent to the first mentioned well for water, shortly after the pollution took place. All the people of the locality, and especially all those who had the fever, had used the Spring alley well, some of them continued to do so after the fever broke out, some had also used the water of the other well, but none had used the city water from the Schuylkill until after the outbreak.

The chain of evidence thus seems unusually strong and clear. My analyses of this well water were made during the prevalence of the epidemic and while new cases were developing. They are as follows:

		I.	II.	III.	IV.
Free ammonia	Parts per million,	0·034	0·010	0·010	0·058
Albuminoid ammonia	Parts per million,	0·116	0·080	0·090	0·140
Chlorine	Parts per million,	2·3	2·6	2·3	2·4
Total solids	Parts per million,	30·5	—	—	28·0
Nitrogen as nitrates and nitrites	Grains per imp. gal.	—	1·94	—	2·45
Nitrogen as nitrites only	Grains per imp. gal.	—	0·096	—	0·032

The samples were collected in the order of the numbers respectively, Aug. 10, 12, 13 and 21; the last three early in the morning and the first at noon. No. II was taken nine hours after a heavy rainfall lasting 1½ hours. No. IV was collected half an hour after a short but heavy shower. The water, nevertheless, remained quite clear. All the samples were bright and colorless, with no odor, and having a refreshing taste. The water was quite hard.

In order to judge properly of these analyses, I give, for the sake of comparison, analyses of a hard and of a soft water which are typical of the purest well waters in Germantown and perfectly free from contamination:

	Free NH_3.	Albuminoid, NH_3.	Chlorine.	Solids.
Hard water, . .	0·010	0·050	2·2	34·0
Soft water, .	0·014	0·034	0·7	6·0

The hardness in Germantown waters is due chiefly to sulphates. It will be noticed that the chlorine in the Spring alley well water was

not greater than is usual in pure hard waters here. What is still more remarkable is, that the other well in Spring alley contained not a particle more chlorine, notwithstanding that enormous amounts of free ammonia (from 2·7 to 5·2 parts per million) were present, with large excess of albuminoid ammonia, and large amounts of nitrates and considerable nitrite. In these two cases, therefore, *freedom from excess of chlorine did not prove freedom from contamination by sewage*, according to the rule usually stated. Three privies stood close to the second well, hence the chlorine test was of no value at all in this latter case. It may be added that the test was repeatedly made with the same result.

The following well waters of Germantown, which I analyzed in 1878, are examples of what we may find in wells in highly dangerous situations, which tend to confirm Mr. Ekin's statement, that dangerous wells may contain a small amount of organic matter along with considerable nitrate, and that in such cases the opinion to be rendered will depend very much on the presence of the latter:

	I.	II.	III.
Free ammonia.....Parts per million,	0·040	0·022	0·016
Albuminoid ammonia, " "	0·046	0·058	0·080
Chlorine.....Grains per imp. gal.,	3·2	3·2	2·7
Nitrates.....considerable.	considerable.	large am't.	
Nitrites.....	traces.	—	—

Hardness in all these waters, about 12°, due to sulphates chiefly. The situation of the wells is as follows: No. I, Mechanic street west of Morton street, in close proximity to a number of privies which are on somewhat lower ground; soil—loose, micaceous sand. No. II, Haines street, near M. E. Church; pump on street pavement, exposed to infiltration from gutter, etc. No. III, Haines street east of Hancock street; well under kitchen porch. The owner felt anxious about it, and asked to have the water analyzed. I have not heard of any sickness having been attributed to any of these wells.

The chlorine is very slightly in excess of the amount frequently found in pure hard waters of this district, and it would, therefore, by itself, scarcely be considered a suspicious circumstance.

I will conclude this paper with the analysis by Prof. Nichols of a well water in Fairhaven, Massachusetts, published in the Massachusetts State Board of Health Report for 1879, which will be interesting in comparison with the foregoing analyses. It should also be stated that my analyses have shown that many other wells in Germantown

are *far more polluted* than this one, particularly those in crowded localities.

Well in Fairhaven, Massachusetts.

Free ammonia,	0·01	parts per million.	
Albuminoid ammonia,	0·13	"	"
Chlorine,	3·3	"	100,000.
Total solids,	20·3	"	"
Nitrates,	Not in large amount.		

The privy vault was *one hundred feet* distant from the well. The soil was composed of gravel and loam. On the 7th of September the husband was taken quite ill with typhoid fever, and his dejections passed freely into the privy vault. On September 30, and during the next twelve days, his wife and six children were successively taken with typhoid fever, and another child took the same disease a few days later. Thus, every member of this one family who had used the water of the well were ill with typhoid fever. The water was probably poisoned by the excreta of the husband, and the usual incubative period intervened before the disease appeared amongst the rest of the family. The chlorine in the water was found to be one part per one hundred thousand, more than the natural amount for that locality. In order to compare it with that in the other analyses given above, multiply by $\frac{7}{10}$ to reduce to grains per imperial gallon. The date of the analysis was *October* 17, within a day or two of the development of the last case of fever.

A Great Storm.—M. Rouger has communicated to the French Academy an account of a violent storm at Laigle, in September last. Between 9.30 and 11 P.M. there were at least 4700 flashes of lightning; sometimes there were as many as three flashes per second. The rain began about 10·45 and lasted for about an hour and a half; there was no hail. The thunder was almost continuous, like a kind of buzzing, occasionally interrupted by heavy rollings. On one of the buildings that was struck there was a zinc conducting pipe, for carrying off rain water, which was pierced with three holes, two of which were square and the third round, as if made by a bullet. They all occurred where the walls of the pipe were doubled, and in each instance the burr was inward in the inner pipe and outward in the outer pipe.—*Comptes Rendus.* C.

THE BASIC DEPHOSPHORIZING PROCESS; WHAT IT IS AND WHAT MAY BE EXPECTED FROM IT.

By JACOB REESE.

A paper read before the Engineers' Society of Western Pennsylvania, Dec. 21, 1880.*

A slag is said to be basic when it is composed of metallic oxides; or, in other words, when the base of the slag is a metal the slag is said to be basic. Oxide of iron and oxide of calcium are true basic oxides, and form highly basic slags.

A slag is said to be acidulous when it is composed of a mettalloid, such as silicon, phosphorus or sulphur, oxidized to silicic acid, phosphoric acid, or sulphuric acid, and these acids combine with a base forming silicates, phosphates or sulphates. When these compounds are present in a slag in a large degree it is said to be of a highly acid character.

When a metallic process is conducted in the presence of a highly basic slag it is called a basic process, and when it is conducted in the presence of a highly acid slag it is called an acid process.

The process by which the ancient Romans and Britons made their iron is known as the Catalan process. It was conducted in an open chamber, surrounded on all sides and the bottom with a lining of charcoal dust. The fuel was used in this metal chamber admixed with the iron ore and metal. The slag present in this metal chamber, and produced by this process, was principally composed of oxide of iron; hence the Catalan was and is a basic process.

The blast furnace is lined with stone or brick, both of which are highly acidulous, and, although limestone is used as a flux, owing to the silicious character of the ore and ash of fuel the slag is of an acid character, as will be seen by the following analysis:

Silicic acid,	58
Lime,	23
Alumina,	8
Magnesia,	2
Manganese,	–
Oxide of iron,	9

Hence the blast furnace process is an acid process.

* In republishing the paper of Mr. Reese on this very important subject, this journal does not endorse the *chemistry* of the article.

Henry Cort, who invented the puddling process, was the first to separate the fuel from the metal chamber; he lined his metal chamber with sand (silicic acid); the slag was highly acidulous, and Cort's puddling process was an acid process.

Dr. Roebuck, the inventor of the refinery fire, lined the metal chamber with cast iron water boshes. The fuel was admixed with the metal. The refinery slag was highly basic, as is shown by the following analysis:

Oxide of iron,	85·0
Silicic acid,	14·0
Alumina,	0·5
Magnesia,	0·5

Hence the refinery process was a basic process.

Samuel Rodgers improved Cort's puddling process by putting an iron bottom and iron plates into the puddling furnace and lining the metal chamber with oxide of iron instead of sand. The following analysis of the slag shows it to be highly basic:

Oxide of iron,	89·0
Silicic acid,	9·0
Alumina,	1·5
Magnesia,	0·5

Hence Rodgers' puddling process is a basic process.

The Bessemer process, invented by Henry Bessemer, is conducted in a converter which is lined with ganister (a highly silicious substance). The slag produced is composed of the following:

Silicic acid,	44·30
Lime,	·65
Protoxide of manganese,	24·55
Alumina,	10·80
Magnesia,	·25
Oxide of iron,	19·45

It is a silicious slag because there is not sufficient basic material to engage all the silicic acid as silicates. And the Bessemer process is an acid process.

In the open-hearth process the metal chamber is lined with sand. When metal and scrap are used the slag is highly acidulous; and the metal and scrap open-hearth process is an acid process.

When iron ore is used in the open-hearth in considerable quantity

the slag is neutral; and the ore and metal open-hearth process may be classed with the basic processes. We therefore have as

Basic Processes.	Acid Processes.
Catalan,	Blast furnace,
Refinery,	Cort's puddling,
Rodgers' puddling,	Bessemer,
Open-hearth ore and metal,	Open-hearth metal and scrap.

The dephosphorizing problem may be summed up in these words: The phosphorus must be oxidized to phosphoric acid, P_2O_5, in the presence of a basic slag, in order that the acid so formed may unite with and be held by a metallic base as a phosphate of lime, or a phosphate of iron. And as silicic acid decomposes a phosphate of lime or a phosphate of iron, and carbonic acid decomposes a phosphate of iron, the slag must be of a highly basic character in order that all the silicic acid formed by the oxidation of silicon shall combine with and be engaged in the slag as silicates. And in order to avoid the reduction of the phosphate by carbonic acid the dephosphorization must take place in the presence of a highly basic slag, and in the absence of carbonic oxide.

In the acid processes before mentioned, as the blast furnace, Cort's puddling, Bessemer converter and the open-hearth with metal and scrap, the silicic acid and carbonic oxide reduce the phosphate to a phosphide; and as a phosphide has a greater affinity for the metal than for the slag the phosphorus is returned to the metal.

In the blast furnace, however, an additional reaction takes place under the following conditions: Carbonic oxide being always present at the zone of reduction, where the ores are deoxidized, the phosphorus accompanies the metal as a phosphide of iron. In case where the slag in the hearth does not contain over 40 per cent. of silicic acid, and does not contain 60 per cent. of basic material, the silicic acid being held as silicates, the oxide of iron contained in the slag in the free state will oxidize a portion of the phosphorus, which, uniting with oxide of iron or lime, will form a phosphate of iron or a phosphate of lime, and exist in the slag in the hearth of the furnace below the zone of carbonic oxide; under these conditions a partial dephosphorization of metal takes place in a blast furnace working on black cinder. The degree of phosphorus thus taken up by the slag will depend upon its basic character and its ability to hold the phosphorus as a phosphate.

In the old basic processes—the Catalan process and the refinery process—the fuel being admixed with the metal, carbonic oxide was always present; hence the phosphate could not exist, even in the highly basic slag, and dephosphorization was impossible. In the basic open-hearth dephosphorization takes place before the elimination of carbon commences, if the phosphoritic slag is removed, and also after the carbon has been consumed and carbonic oxide disappears.

In Rodgers' basic puddling process the chemical reactions are divided into three periods: first, the melting period; second, the boiling period; third, the solidifying period.

During the first period the metal is melted and the oxide of iron is admixed and melted. The chemical reactions which occur in this period are the oxidation of phosphorus and of silicon, and their removal from the metal to the slag. As there is no gas evolved from the oxidation of these elements the metal remains in a state of rest, except so far as agitated by the puddler's tools. If the slag be tapped off just before the close of this period it will be found to contain from 70 to 80 per cent. of the phosphorus previously contained in the pig metal. But if the slag remain with the metal until the silicon is reduced down to ·02 the second period commences, the carbon is oxidized to carbonic oxide, which, passing upward through the slag, attacks the phosphate and reduces it to a phosphide, and, as a consequence, all the phosphorus removed from the metal during the first period (and permitted to remain in the slag) is returned to the metal during the second period. As the chemical reaction during the second period is the oxidation of carbon to carbonic oxide (CO) ebullition takes place, and the metal boils. When the carbon has been reduced down to ·08 the ebullition ceases, the cinder or slag "drops" and the metal solidifies, and, as the puddlers term it, "is brought to nature" during the fluid period.

During the first part of the third period the damper is raised, and the metal which extends above the slag is exposed to an oxidizing flame. The phosphorus is either sweated out of the metal by liquidation or is oxidized by the fluid cinder, in either case, it being oxidized to P_2O_5, it again enters the slag as a phosphate of iron ($_3FeO.P_2O_5$). There being no free silicic acid or carbonic oxide in the slag during this third period the phosphorus remains in the slag until the metal is withdrawn; hence Rodgers' puddling process, when properly conducted, is a true basic dephosphorizing process, being con-

ducted in the presence of a highly basic slag, and in the absence of CO, or free silicic acid.

As phosphorus, silicon and carbon tend to reduce the fusion point of iron in degree to the amount of these elements which the metal contains, it follows that the fusion point of iron is greatly raised by the diminution of these elements, and this is the reason that the iron solidifies during the third period of the puddling process.

In the Bessemer and open-hearth processes the temperature is kept high enough to hold the metal in a fluid condition after the elimination of phosphorus, silicon and carbon, but, at the high temperature required, Rodgers' basic lining (oxide of iron) is fused also, and for this reason the Bessemer converter and the open-hearth have heretofore been lined with a silicious material.

The new basic dephosphorizing process, by which iron and steel may be desiliconized, decarbonized and dephosphorized, and yet be retained in a fluid state, so as to cast it into ingots of iron or of steel, is conducted in a metal chamber lined with lime, which is a basic material, it being the oxide of the metal calcium. By means of a lime lining the required temperature to keep the metal fluid may be employed with but little waste of the lining, and when the lining does waste, it being of a highly basic character, it tends to form a highly basic slag.

When the Bessemer converter is furnished with a lime lining, and the metal is blown in the presence of a highly basic slag until the silicon is oxidized to silicic acid, and this acid unites with bases forming silicates, and the blow is continued until the carbonic oxide disappears, and the metal is further blown in the presence of a highly basic slag, and in the absence of free silicic acid and carbonic oxide, the phosphorus is rapidly oxidized to P_2O_5, which enters the slag, and, uniting with oxide of iron, remains there as a phosphate of iron ($_2FeO.P_2O_5$), and the silicon, carbon and phosphorus are entirely eliminated from the metal. When the slag is of a highly calcareous basic character the phosphate of iron may be decomposed and a phosphate of lime formed ($CaO.P_2O_5$).

When the phosphorus exists in the slag as a phosphate of iron, if carbonic oxide be present, it will rob the phosphate of its oxygen, forming carbonic acid, and the iron and phosphorus unite as a phosphide of iron and return to the metal. But when the phosphorus exists in the slag as a phosphate of lime carbonic oxide will not reduce

it. If, however, silicic acid is present in a free state it will rob the phosphate of its base, forming a silicate of lime, and the carbonic oxide will rob the acid of its oxygen, and the phosphorus be returned to the metal.

In the practice of the basic dephosphorizing process in the Bessemer converter the silicon, carbon and phosphorus are entirely removed, and the metal is very nearly pure iron. If a small quantity of ferro-manganese or ferro-silicide is then added to partly reduce the oxygen, and the metal is cast into ingots and rolled, it will be found to possess a highly fibrous character, much superior to fibrous wrought iron made by the puddling process. And if sufficient ferro-manganese or ferro-silicide is added to thoroughly deoxidize the metal, when rolled, it will be found to possess a fine crystalline texture. In both these cases the ingot iron so made will be very ductile. When ingot steel is desired, the metal, when desiliconized, decarbonized and dephosphorized, should be removed from the slag, and then deoxidized and recarbonized in the usual manner.

When an open-hearth is furnished with a lime lining, and the metal is held at a high temperature in the presence of a highly basic bath until the silicon and carbon are eliminated and the silicic acid is engaged as silicates, and carbonic oxide disappears, and the slag is still sufficiently basic, the phosphorus is rapidly eliminated and remains in the slag as a phosphate of iron, the metal may then be treated with ferro-manganese or spiegel for deoxidizing and recarbureting it.

In both the Bessemer and the open-hearth practice it is desirable that the metal should be removed from the presence of the phosphoritic slag before the ferro-manganese or spiegel is added, as the chemical reactions, which take place when these elements are added, tend to carry a portion of the phosphorus from the slag back into the metal.

The quantity of slag required will depend on its degree of basic purity and on the amount of silicon and phosphorus to be eliminated, the essential requirement being that the slag shall possess sufficient basic material to engage all the silicic acid as silicates, and all the phosphoric acid as phosphates. To secure these requirements in excess, the weight of the slag will range from 25 to 30 per cent. of the weight of the metal.

In the economy of the new basic dephosphorizing process it is desirable to produce metal for this process containing as little silicon

as practicable, so as to prevent the appearance of silicic acid in the slag as far as possible. And as the reduction of silicon is a reduction of the source of heat, it is desirable to increase the percentage of phosphorus in the metal in proportion to the heat units withdrawn by the reduction of silicon. Therefore the most desirable metal for the new basic dephosphorizing process is that which is low in silicon, and containing from 2 to 3 per cent. of phosphorus.

When metal, containing 2 per cent. of phosphorus, is treated in a lime-lined converter, and in the presence of 25 per cent. of a highly calcareous basic slag, the slag, when withdrawn, will be found to contain 18·32 per cent. of phosphoric acid to weight of slag, or 4·58 per cent. of weight of the metal.

In order to obtain a metal from any class of ores, suitable for the new basic dephosphorizing process, containing a minimum of 2 per cent. of phosphorus, and to economize the cost of the basic calcareous slag, it is proposed to use this calcareous phosphoritic slag as a flux in the blast furnace in place of so much limestone. When this slag, containing 18·32 per cent. of phosphoric acid, is used in a blast furnace in proportion to ¼ ton of slag to 1 ton of metal produced the phosphate is reduced by the carbonic oxide and silicic acid to a phosphide, and the metal produced will contain 2 per cent. more phosphorus than was obtained from the ores from which the metal was smelted.

Thus the phosphorus, which is utilized by oxidation for the development of caloric essential to keep the metal in a highly fluid condition in the basic converter, is again utilized by its reduction in the blast furnace, securing economy and an absolute control of the production of a minimum of 2 per cent. of phosphorus in the metal made from any class of iron ores, which is desirable, as it is more convenient and practicable to eliminate 2 per cent. of phosphorus from the metal by the basic process than it is to dephosphorize a metal containing but $\frac{1}{10}$ of that amount of phosphorus and 2 per cent. of silicon.

The essential requirements of dephosphorization having been determined as set forth, *i. e.*, the oxidation of phosphorus in the presence of a highly basic slag and in the absence of free silicic acid and carbonic oxide, it is proposed to dephosphorize molten metal flowing from a blast furnace by treating it at a low temperature in the presence of a highly basic slag, and withdrawing the metal from the slag after it is dephosphorized and before the oxidation of the carbon takes place, and run-

ning the oxidized metal into pigs, or taking the metal and treating it in the acid Bessemer converter, or in an acid-lined open-hearth.

It is also proposed to dephosphorize molten metal direct from the blast furnace as before described, then to run it, minus the slag, into an open-hearth, and there desiliconize it down to ·025, and then to withdraw the dephosphorized metal and run it into pigs. Such a metal would be low in phosphorus, high in carbon and practically free from silicon, and would be a superior chilling iron for the production of chill rolls, car-wheels, and most excellent for gun metal and malleable castings, and all foundry purposes.

It is also proposed to desiliconize and decarbonize metal in the acid Bessemer converter, and then run it minus the silicious slag into a basic-lined converter or open-hearth and there dephosphorize and refine it, and then run the metal minus the phosphoritic slag into a ladle and deoxygenize and recarbonize it in the usual manner, and cast it into ingots.

Having explained the distinguishing characteristics of the old processes and the essential requisites to dephosphorization possessed by the new basic process, I will now venture a few predictions as to "what we may expect from it."

The basic dephosphorizing process will eliminate all the silicon, carbon, manganese and phosphorus contained in the metal, and produce nearly pure wrought iron.

As the fibrous character of wrought iron is caused by oxide of iron being inter-stratified in alternate lamina with the iron, and as the molten metal in the basic converter will, at the end of the blow, be somewhat oxidized if a small quantity of ferro-manganese be added to it, but not in sufficient quantity to reduce all of the oxygen, the ingot iron produced by the basic dephosphorizing process, when rolled down, will exhibit a highly fibrous texture and possess in a superior degree the properties of ductility, malleability and welding, which are possessed by the best Swedish or Norway iron—therefore the importation of such irons will cease when the basic wrought iron is put upon the market, as the latter will be better and cheaper.

As pig metal designed for the basic dephosphorizing process may be made from the cheapest class of ores, smelted in a blast furnace in which a hot blast of the highest volume and temperature is employed, the metal will be of the cheapest class produced, and as such metal, whether white, mottled or gray, can be put into fibrous wrought iron

at less cost by the new basic dephosphorizing process, than it is now, or can be, put into muck bars by the puddling process. We may expect that the history of the puddling process will be closed at an early day.

By incorporating with the basic metal just sufficient ferro-manganese to thoroughly deoxidize it, the ingot iron, when rolled down, will possess a fine crystalline texture, and yet be tough and ductile. Thus it is conceived that the fluid basic dephosphorizing process will not only produce a superior quality of steel containing any degree of carbon, chemically combined, from ·00 to 2 per cent., but it will also produce wrought iron, both fibrous and crystalline, of a quality superior to any produced heretofore by any other process. And as the degree of expansion and contraction between any given temperatures will be increased in proportion to the amount of carbon contained in a metal, and as the fluid basic dephosphorizing process is capable of producing *ingot iron free from carbon* we will be able to produce by this process a superior quality of wrought iron, possessing all the essential characteristics required for *structural purposes.*

Believing, as I do, that graphitic carbon is held in the pores of the physical structure, and that the portion of carbon, which is said to be chemically combined, is held in the pores of the chemical structure, the most pure iron, having its pores empty, when re-carbonized will take up a greater amount of carbon and exhibit greater elasticity and resilience than less pure iron so carburized. Hence we may expect to produce by the basic process *spring steel of a superior quality.*

As the most pure iron will take up the largest amount of chemically combined carbon, or, in other words, will accommodate more carbon in the chemical pores, when such iron is highly carburized, the steel will be harder, and the texture more dense; therefore we may expect to produce moldboards, landsides, plow points, and other agricultural steels of superior quality, by the basic dephosphorizing process.

As pure iron is silver white, of a very agreeable, mild, and at the same time brilliant lustre, steel produced from such iron will possess a finer texture and be capable of exhibiting a higher polish and a more beautiful lustre than iron or steel of less purity. Hence we may expect to produce steel for cutlery, cutting tools and other polished work, of a superior quality, by the basic dephosphorizing process.

The new process will produce rails of ingot iron or of any degree of carburization desired, and I believe that rails containing ·60 to ·75

of carbon, made by the basic process, will be stronger, tougher and wear double the tonnage of rails now made by the Bessemer acid process.

The basic process will produce better iron for *tin plate*, for *galvanizing*, for *stamping* and *drop forgings* than has ever been produced by any other process.

It is proposed to produce pure iron by the basic process and then re-carburize it by infusing plumbago into the metal, and thus avoid the reactions which take place in re-carburizing by the use of ferro-manganese or spiegel. Basic steel may be produced by this method possessing the peculiar characteristics of tool steel.

Pig metal for the basic process may be made from all kinds or qualities of iron ore, but for reasons before mentioned it is desirable that the metal produced shall be low in silicon, and contain not less than 2 per cent. of phosphorus. Hence by the utilization of phosphoritic ores the centre of greatest production of iron and steel may adjust itself to the economy of the basic process.

In the economy of the basic process the blast furnaces and the converters, or the open-hearths, will be located near each other, so as to save fuel, and freight on the phosphoritic slag.

The metal produced by the basic process being in a fluid condition, may be cast into ingots of any desirable shape, and as mechanical operations will be employed to work these forms in large masses the old rolling mills may not prove economical.

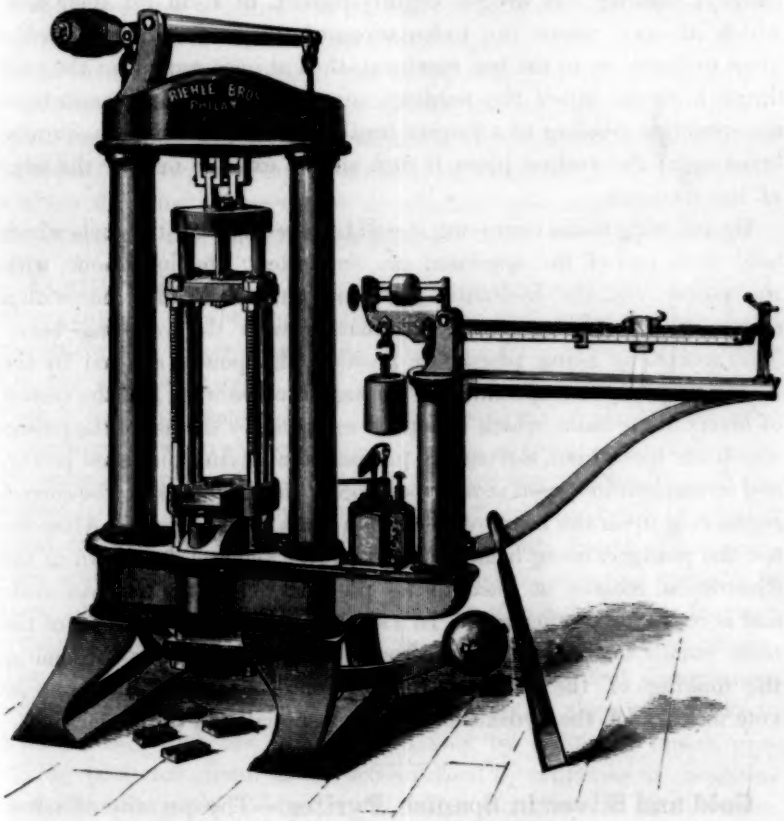
As ingots designed for plates may be cast of any desired width, and as the ingots will be reduced to plates principally by automatic process of rolling, nail plates, tank and ship plates will be produced at less cost than such are now produced by the old processes.

In conclusion, I believe that the fluid process, *i. e.*, the Bessemer and open-hearth with the basic dephosphorizing improvement, will in time supersede all others for the production of iron and steel, and will ultimately enable the United States to become the greatest exporter of iron and steel in the world.

Electric Motor.—It has been proposed to build dams upon the Seine, so as to create a water power which could be transmitted, by Siemens or Gramme machines, to different parts of Paris, and used for drawing vehicles.—*Chron. Industr.* C.

RIEHLE BROTHERS' IMPROVED VERTICAL TESTING MACHINE, 50,000 POUNDS CAPACITY.

The illustration represents one of Riehlé Brothers' improved machines for testing specimens of material, up to 50,000 pounds, by tensile, transverse and crushing strains. It is compact, strong and accurate, and well adapted for the purpose it is designed for. The shape and style are good, the various parts substantial in construction, and the workmanship unexcelled throughout the whole machine.



It is composed entirely of iron, brass and steel, and weighs about one ton. The dimensions are as follows: Extreme height, 8 feet; extreme length, 7 feet; extreme width, 2 feet 6 inches; motion of plunger of jack, 8 inches. This apparatus can test a specimen by tensile strain

from 4 or 5 inches up to 24 inches in length; transverse specimen up to 14 inches, and by the application of a superior beam to still greater length; crushing specimens, 7 inches in diameter and less, up to about 20 inches. This is a wider range of test than any machine of corresponding capacity that is made. In testing flat specimens of metal and other material with wedge grips trouble has often been experienced by the specimen slipping on or near one edge, caused by a variation in the density of the fibres of the material; this is obviated by a simple device conceived by one of the members of the firm of Riehlé Bros., namely, making the wedges slightly convex in form on their face, which at once causes the indentations of the surfaces of the wedge grips to fasten on to the test specimen, thus at once rendering the pull direct, however much the tendency may be, during the operation, of the specimen yielding to a tearing break caused by the metal naturally breaking at the weakest place, if such should exist on or near the edge of the specimen.

By referring to the engraving it will be observed that the tools which hold each end of the specimen are connected; the lower one with the power, viz., the hydraulic jack and pump, and the other with a system of multiplying levers, terminating with the weighing beam. The specimens being placed in position, the power exerted by the hydraulic pump is communicated through the specimen and the system of levers to the beam, which is kept in equipoise by the use of the poises, which are moved out, during the process of applying increased power, and consequent increased strain upon specimen, thus securing the correct registering upon the beam of the strain upon the specimen. After the test the plunger, being balanced by the lever and weight shown in the illustration, returns at once to its position before the test was made and is ready for another test. In a screw machine, the returning of the tools entails a laborious and tedious operation, almost as tiresome as the making of the test; for that reason, the public has cast its vote in favor of the hydraulic machine, especially in large machines.

Gold and Silver in Spanish Pyrites.—The quantity of silver which has been extracted in England, as an accessory product of the pyrites imported from Spain, has been 18,000 ounces, and the quantity of gold about 700 ounces. A new industry has thus arisen from a product which no one suspected a few years ago to have any merchantable value.—*La Gaceta Industrial.* C.

Circulation of Air in the St. Gotthard Tunnel.—M. Stapf has been giving careful attention to the variations in the air currents between the two openings at Göschenen and Airolo. He finds two principal causes to be operative in these changes: First, the southern opening is 30 metres (32·809 yards) higher than the northern, which represents a pressure equivalent to that of a column of air 36 metres (39·371 yards) high at the subterranean temperature; second, the difference of barometric pressures upon the two declivities of the mountain. If the external temperature was always lower than the internal, if the barometric pressure was the same at each side, and if there were no modifications of velocity due to the heating and expansion of the air or to the friction against the walls,—the draft would always be southward. Meteorological observations are regularly taken, both at Airolo and Göschenen, to determine the elements which are required in order to know, monthly or annually, the number of days for which a given direction of current or an absolute calm may be expected in the interior of the tunnel.—*Les Mondes.* C.

Fugitive Spectra.—Trouvelot, in the observations at his physical observatory in Cambridge, during the past four years has examined the sun with a spectroscope daily, whenever the weather would admit. On the 30th of August, 1877, at 2.30 P.M. he noticed for the first time a singular phenomenon. He was minutely exploring the solar circumference when suddenly, upon a group of brilliant protuberances, the solar spectrum was invaded with the rapidity of lightning and traversed by very brilliant linear spectra, which succeeded each other with great rapidity and ran through the whole visible length of the principal spectrum. He has subsequently turned his attention specially to these phenomena, and finds that they are of comparatively frequent occurrence. Their presence may be explained by two hypotheses. The first attributes them to meteors and the consequent disturbances which are supposed to give rise to the corona; the second looks to solar forces, which are brought into play by unknown causes, producing profound disturbances accompanied by eruptions of incandescent materials, either solid or liquid, which are thrown in all directions to great heights in the solar atmosphere. Trouvelot inclines to the latter view, but he is continuing his observations in the hope of finding positive evidence to show whether the bodies which produce the spectra fall into the sun, or are ejected from it.—*Ann. de Chim. et de Phys.* C.

Treatment of Boiler Incrustation.—Casalonga reports favorably upon the system of Dulac for preventing and removing incrustations. There are two distinct operations—one intended to prevent the crystallization and conglomeration of the deposits, the other to clear the water from these deposits, by means of circulatory currents passing through small boxes, which can be readily removed and in which the deposits are made. An experiment has been tried upon the boilers of MM. Raimbert and Geoffroy. The boilers were first picked and cleansed, and after twelve months' trial they were found as clean as upon the first day, the 150 kilogrammes (330·69 pounds) of mud which had been introduced in the feed water being found collected in the decanting boxes. A noteworthy fact, which shows the purity of the steam, is that the walls of the steam reservoir, the dome and the main pipe are as clean as if the metal was new. The system is said to be especially applicable to vertical boilers of all descriptions.—*Chron. Industr.* C.

Thermo-Chemical Transformations.—Berthelot has shown that every chemical change which is accomplished without the intervention of any foreign energy tends towards the production of the body or system of bodies, the formation of which sets free the greatest amount of heat. Such a final system is not always reached at once, by the first transformation of the original bodies; but it often happens that these bodies form, in the first place, new compounds, which are modified in their turn by successive steps. In order that these successive modifications may take place, it is necessary that each one of them, taken separately as well as their aggregate sum, must be accompanied by a disengagement of heat. There can be no gain of energy due to internal action alone in any of the intermediate changes. Berthelot explains in this way the various phenomena which were attributed by Schönbein to the opposite electrical polarities of ozone and antozone. He thinks that oxygenated water contains an excess of thermal energy, and this excess is gradually expended in the formation of new compounds, engendered by a suite of metamorphoses, which is impossible in bodies that have no such reserves. He regards a similar theory as applicable to a multitude of chemical phenomena, and especially to the material metamorphoses which preside over the fermentations and the nutrition of living beings.—*Ann. de Chim. et de Phys.* C.

Swiss Triangulation.—The operations in the neighborhood of Aarlberg, under the direction of the Spanish General Ibanez, for measuring the base of the network of Swiss triangulation, have been very satisfactory. The base has been measured twice. The result of the first measurement was 2400·087 metres (1·502 miles); the second operation, which was conducted entirely independently of the first, for the purpose of verification, gave 2400·085 metres. The difference between the two measurements was only two millimetres, or less than one ten-thousandth of one per cent. The place chosen for the base is on the route of Sisselen, where a perfectly straight and nearly horizontal line may be drawn for a distance of about three kilometres (1·864 miles). Similar measurements are to be made in the valleys of Tessin and of the Rhine.—*Les Mondes.* C.

Color and Liquefaction of Ozone.—Hautefeuille and Chappuis find that the isomeric transformation of oxygen into ozone under electric influence obeys simple laws. When the electric discharges cease, the mixture of oxygen and ozone ceases to be homogeneous; nevertheless it is preserved without appreciable change if a uniform temperature is maintained below the freezing point. In consequence of this relative stability of the ozone they have been able to compress the mixture and to experiment with the ozone under a pressure of many atmospheres. In increasing the pressure the capillary tube becomes of an azure blue; this color deepens in proportion to the reduction of the gaseous volume; finally the gas is of an indigo blue, and the meniscus of mercury, when seen through the gas, appears of a steel blue. The blue color of the gas becomes less intense and the mercury resumes its customary metallic aspect when the tension is diminished. Under a pressure of 75 atmospheres a thick white mist appears the moment the valve is opened. The ozonized oxygen, therefore, requires only one-fourth as great a pressure as pure oxygen, in order to secure signs of liquefaction and solidification. Ozone, however, is a little more difficult to liquefy than carbonic acid. The mixture of oxygen and ozone, containing an explosive gas, should always be compressed gradually and at very low temperatures; if these precautions are not observed the ozone decomposes, with an escape of light and heat, and there is a strong explosion, accompanied by a yellowish flash. Under a pressure of ten atmospheres the azure tint is so intense that it can be readily seen in a tube of one millimetre (·0394 inch) internal diameter.—*Comptes Rendus.* C.

Diurnal Variations of the Barometer.—G. H. Simonds has computed the barometric coefficients of daily variations from observations made at thirty stations scattered over the globe. The average duration at each station was something over ten years. Under the tropics the effect of latitude is scarcely perceptible, but between the latitudes of 20° and 60° the value of the quadrantal component decreases ·001 inch per degree of latitude. The calculations and the discussions which have resulted from them confirm Sir John Herschel's views, in regard to the universality of the phenomenon, and Chase's explanation of the cause.—*Les Mondes.* C.

Radiant Matter.—Hittorf considers that the results of Crookes' researches upon radiant matter are not essentially different from those which he himself published in 1869. The only novelty which he recognizes consists in Crookes' admission of a fourth state of aggregation. He does not regard this admission as necessary, and he is unwilling to admit that the dark space near the negative electrode represents the mean length of molecular path. He attributes the radiant matter to particles mechanically torn from the electrodes, which are charged with static negative electricity. These particles move in a straight line, with enormous velocity and affect, by a molecular electric convection, the whole track of the current between the two poles.—*Les Mondes.* C.

Electric Light in Slate Quarries.—The stability of schistose rocks is so much greater in subterranean galleries than in superficial excavations, which are exposed to the disintegrating influences of air and moisture, that there are many advantages in quarrying slates by means of mining shafts and galleries. The greatest objection to such quarries is their obscurity, which diminishes the net results of the labor and renders the proper surveillance of the walls more difficult. These inconveniences have been partly remedied by establishing regular rounds, which are constantly traversed by trustworthy watchmen; partly by replacing the old, smoky miners' lamps, in the first place by gas, and more recently by the electric light, which appears to furnish a complete solution of the problem. In the quarries of Angers all of these experiments have been successfully made, and it has been found that the electric light is about eight per cent. cheaper, and far more satisfactory than gas.—*Ann des Mines.* C.

Franklin Institute.

HALL OF THE INSTITUTE, January 20th, 1881.

The stated meeting was called to order at 8 o'clock P. M., the President, Mr. William P. Tatham, in the chair.

There were present 123 members and 45 visitors.

The minutes of the last meeting were read and approved.

The Actuary presented the minutes of the Board of Managers, and announced that 14 persons were elected members of the Institute at the last meeting of the Board.

The Secretary reported the following donations to the Library:

Annual Report of the Department of Statistics and Geology of the State of Indiana, 1879.

Annual Report of the Indiana State Board of Agriculture, 1879.

Transactions of the Department of Agriculture of the State of Illinois, 1878. From L. S. Ware.

Report of Select Standing Committee on Immigration and Colonization. Canada. 1878.

University of California College of Agriculture. Supplement to the Biennial Report of the Board of Regents. 1879.

Annual Report of Massachusetts Agricultural College. 1880.

Annual Report to the Council of the City of Manchester on the Working of the Public Free Libraries. 1879–80.
From the Council.

The Gold Standard; its Causes, Effects and Future. Philadelphia: H. C. Baird & Co., 1880. From the Publishers.

Annual Report of the Supervising Inspector-General of Steam Vessels to the Secretary of the Navy, for 1880.
From the Inspector-General.

Verhandlungen des Naturhistorisch-Medicinischen Vereins zu Heidelberg. N. S. Vol. 2. Pt. 5. 1880. From the Society.

Holyoke Hydrodynamic Experiments made by Holyoke Water-power Company. 1879–80. From the Company.

Annual Report of the Commissioner of Patents for 1879.
From the U. S. Patent Office.

Act and Bull. By Lewis A. Scott.

Monetary Questions Viewed by the Light of Antiquity. By R. N. Toppan.

Proceedings of Numismatic and Antiquarian Society of Philadelphia. 1865–66.

Falsifications of Ancient Coins. By S. K. Harzfeld.

Remains of an Aboriginal Encampment at Rehoboth, Delaware. By F. Jordan, Jr. Philadelphia, 1880.

From H. Phillips, Jr., Secretary of the Numismatic Society of Philadelphia.

The Actuary read the

Annual Report of the Board of Managers.

The Board of Managers of the Franklin Institute of the State of Pennsylvania, for the Promotion of the Mechanic Arts, respectfully submits the following report for the year 1880:

Members.—During the year 165 members have been elected, and 24 have resigned.

Treasurer's Report.—The following is a condensed summary of the Treasurer's report for 1880:

Receipts.

Balance on hand Jan. 1, 1880, .	$1,405 85	
Investments of the Institute paid off, .	3,000 00	
Current receipts from all other sources, .	11,567 44	
		$15,973 29

Payments.

Amounts re-invested, . . .	$2,526 25	
All other current payments, . .	11,937 03	
Balance on hand Dec. 31, 1880, . .	1,510 01	
		$15,973 29

This statement shows our current expenses greater than the current receipts.

It is greatly to be desired that by an increase of membership this state of affairs should be reversed.

Journal.—The Journal continues under the same general management as heretofore. The financial results of the publication show that it is more than self-supporting, and it is believed that this is due to the practical value of the matter published.

The size of the monthly Journal has been increased by the addition of eight pages, making 80 pages of reading matter. Manufacturers are recognizing the Journal as an excellent means of advertising.

Library.—The gradual increase of the Library has been continued, as is exhibited by the report of your Committee on the Library.

Although new bookcases were added in 1879 and 1880, there is still not enough room for the convenient arrangement of the books, and this evil must increase until a larger library room shall be provided.

Lectures.—In the beginning of the year Mr. Charles A. Ashburner, of the Pennsylvania Geological Survey, gave two lectures on petroleum, and the course was continued by Mr. A. E. Outerbridge, Jr., on the art of coining, and the spectroscope; Dr. Robert Grimshaw, on saws; Prof. Rachel L. Bodley, on structural botany; D. S. Holman, on motion in "not living" matter; Dr. Isaac Norris, on the physical properties of metals; Hector Orr, on printing; J. B. Nicholson, on book-binding; John Sartain, on engraving; Henry Bower, on glycerine; Dr. Carl Seiler, on vocal acoustics, and Prof. Joseph Remington, on the metric system.

In the fall, the course was opened by six lectures, given by Prof. John M. Child, on the mathematics of physical science, followed by three by Dr. Seiler, on applied acoustics; lectures by Prof. Rachel L. Bodley, on household chemistry; Mr. Reuben Haines, on water; Prof. Barbeck, on microscopic botany, and Prof. E. J. Houston's holiday lecture on electricity—all of which have been largely attended.

Practically, the lectures of the Institute are now free to the public. By the resolution of the Board, seats are retained for members until five minutes to 8 o'clock, after which all who come are made welcome, and, from the interest taken in the Institute by many visiting it for the first time, the plan cannot fail to be productive of good, and a number have expressed a desire to join, and aid all in their power to enhance its future usefulness. The average attendance since the change has been about two hundred persons, while upon two occasions nearly four hundred were crowded into the hall, proving how entirely inadequate the lecture room is to accommodate all who wish to attend, and how much more good could be done if the present valuable course of lectures were delivered in a larger hall.

Drawing School.—The increase in the number of pupils applying for instruction in this department of the Institute is very gratifying to the Board. Mr. Philip Pistor, the Principal of the school, reports 96 pupils attending, and the interest they take in their studies, and the emulation excited by the Bartol scholarships, show that this important work of the Institute is properly appreciated.

The course is a progressive one, and includes instruction in mechanical, architectural and topographical drawing, both free hand and instrumental, extending over three years; but pupils, if sufficiently advanced, may select any subject of importance to them, and receive in it individual instruction. Three evenings in the week, instead of two, as heretofore, are now devoted to the school, and, as the increase of pupils is about 33 per cent. over last year, it was necessary to give notice to the Pennsylvania Museum and School of Industrial Art that the arrangement of a joint occupation of the rooms would have to cease, and they have accordingly moved elsewhere. The Board regret extremely the necessity of the action, and the severance of the very pleasant relations which have always existed between the two schools.

The facts presented in this report of the condition and work of the Institute, show that, while it is nearly self-supporting, as at present constituted, its usefulness is cramped in every department but one, by want of room in the hall which we now occupy.

The library room and the lecture room are entirely too small, and the chemical and physical laboratories attached are altogether inadequate.

The cabinet of minerals has been stored elsewhere for want of room, and the models are scattered and visible everywhere on the tops of the bookcases. The drawing school alone has room to grow.

It seems to the Board that the time has arrived for an appeal to the public for means to place this Institute in a building large enough to enable it to meet the public wants.

Unlike other institutions of similar character elsewhere, the Franklin Institute has received no appropriations of money from either State or city, yet it is altogether a public charity.

It is true that we neither feed the hungry, clothe the naked, nor heal the sick; but, on the other hand, our efforts are to dry up the sources of hunger, destitution and disease, and to avert these evils by the diffusion of such knowledge as strengthens and directs the hands of the bread winner, cheapens the cost of food and habitation, and improves the construction of dwellings.

Our charity makes no paupers; for, however much it may benefit an individual, it never diminishes his feeling of independence, for it helps those who help themselves.

The Board renews the appeal made last year to the members to aid

the Institute by adding to their number. During the past year 70 persons were nominated and elected at the instance of a single member.

By order of the Board,

W. P. TATHAM, *President.*

THE LIBRARY.

The Committee on the Library respectfully reports for the year ending December 31, 1880.

The number of volumes ordered by the committee from publishers was 81.

	Bound.	Unbound.
Number of volumes received from publishers (which includes orders given previous to 1880),	150	135
Number of volumes received for notice in Journal,	28	1
Number of volumes received as donations,	216	707
Number of volumes received as exchanges,	101	
Number of volumes received other than exchanges,	71	
Total number of volumes added in 1880,	566	843
Number of volumes in Library Dec. 31, 1879,	14,813	
Number of volumes (bound) in Library Dec. 31, 1880,	15,379	
Number of volumes repaired during the year,		24
Number of circulars received during the year,		571
Number of new exchanges ordered,		18
Number of exchanges discontinued,		14

Among the important donations were twenty volumes of the "Publication Industrielle," by Armengaud, from Mr. Frederick Graff; "Steam Boilers, their design," etc., by Schock, from Mr. B. H. Bartol; "Coney's Foreign Cathedrals," from Dr. Isaac Norris, and the "Annales Industrielles," from Mr. L. S. Ware.

A number of valuable exchanges for the Journal of the Institute, and for duplicate volumes of books in the Library, have been effected during the year.

A number of serial publications have been completed, and many books requiring it have been rebound.

The books purchased with the income from the Bloomfield Moore fund have been marked by an appropriate label, indicating the generous donation made to the Library from this source.

The number of members and other persons making use of the Library cannot be given, but the committee can report an evidently

increasing interest in, and use of, the Library. With the collection of standard works, embracing all the departments of art and science, to be found in the Library, your committee would urge upon the members their influence to extend the list of membership of the Institute, believing that in the benefit to be derived from the use of the Library will be found the full value of the annual dues for membership.

CHAS. BULLOCK, *Chairman of the Committee.*

The Secretary read memorials of the late George R. Barker and Dr. Alexander Wilcocks, and appropriate resolutions were passed.

The tellers of the election held this day presented their report, and in accordance therewith the President declared the following members elected as officers and managers:

President, William P. Tatham.

Vice-President, Charles Bullock.

Secretary, Dr. Isaac Norris.

Treasurer, Frederick Fraley.

Managers to serve three years, Prof. Pliny E. Chase, Frederick Graff, Coleman Sellers, Washington Jones, W. L. Du Bois, A. E. Outerbridge, Jr., Theodore D. Rand and Joseph M. Wilson.

Auditors, William B. Cooper and Lewis S. Ware.

The President stated that no nomination had been made at the December meeting for Trustee of the Pennsylvania Museum and School of Industrial Art, but that the by-laws governing the subject of nominations and elections did not apply to the office, which had been created since their adoption. It was competent, however, for the Institute to elect a representative at this time, and he thought it would be better to have this done.

Mr. Mitchell moved that the President be authorized to cast the vote of the Institute for Dr. Norris, saying that the latter gentleman had been a worthy representative of the Institute and entirely in harmony with the other trustees. The motion was agreed to, and the President, casting the vote, declared Dr. Norris elected.

Mr. Mitchell moved that a vote of thanks be tendered the tellers for their services, which was carried unanimously.

Among the novelties shown was Kriebel's vibrating valve engine, designed for use on farms, and by people who cannot afford to employ engineers, or to use machinery liable to get out of order and require repairs. One part of the valve vibrates with the cylinder, and is a

part of the same, while the other part is stationary and is held to the vibrating part by springs which take up the wear of the valve. The engine may be easily reversed without the use of a link, and a movable plate between the valve surfaces enables the engineer to adjust the cut-off to any desired point. Engines of this type have been in use in Texas for more than two years. The chief claim of the inventor is simplicity of construction.

Mr. Kriebel, by a photograph projected upon the screen, explained the construction of the valve, and exhibited the engine in operation, and showed how readily it could be reversed.

Mr. Orr inquired as to the power of the engine exhibited, and was told that it was eight horse-power. In answer to other inquiries Mr. Kriebel stated that the earlier engines of this type were built in Texas, but that this particular engine was not.

Dr. Norris read a paper describing Mr. Thomas S. Speakman's proposed tidal motor, and the latter gentleman exhibited a model of the apparatus.

Mr. Speakman's paper describing his proposed motor reviewed previous attempts made in the same direction, but in which only the flow of the tide was utilized. His proposed motor is designed to use the vertical force of the ebb and flow of the tide. A reservoir in which the tide water flows is provided with a float, which rises and falls with the tide, and its movement is utilized in driving the piston of a pump. At this city, the tide rises about six feet, and Mr. Speakman claims that he could obtain four strokes per day of the piston of a pump lifting a column of water to that height. The design is to use very large floats and proportionately large pumps. It is also proposed to connect the float with a shaft by means of ratchets, and to raise the speed of machinery driven by this motor to any desired extent by the use of ordinary devices of shafting and gearings. Mr. Speakman presented calculations of the power of the motor with floats and pistons of different diameter, and claimed that the motor would be economical, as the running expense would be trifling in amount.

In answer to questions by Messrs. Tatham, Cooper and others, Mr. Speakman said that the piston was packed tightly, that it would make four strokes a day (that is, two double strokes), that the cost of the power derived was almost nothing beyond interest on the original cost of the apparatus, and that no attempt had been made to reduce the effects of the machine to horse-power.